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(54) CHEMICAL SENSOR RESPONSIVE TO CHANGE IN VOLUME OF MATERIAL EXPOSED TO TARGET PARTICLE

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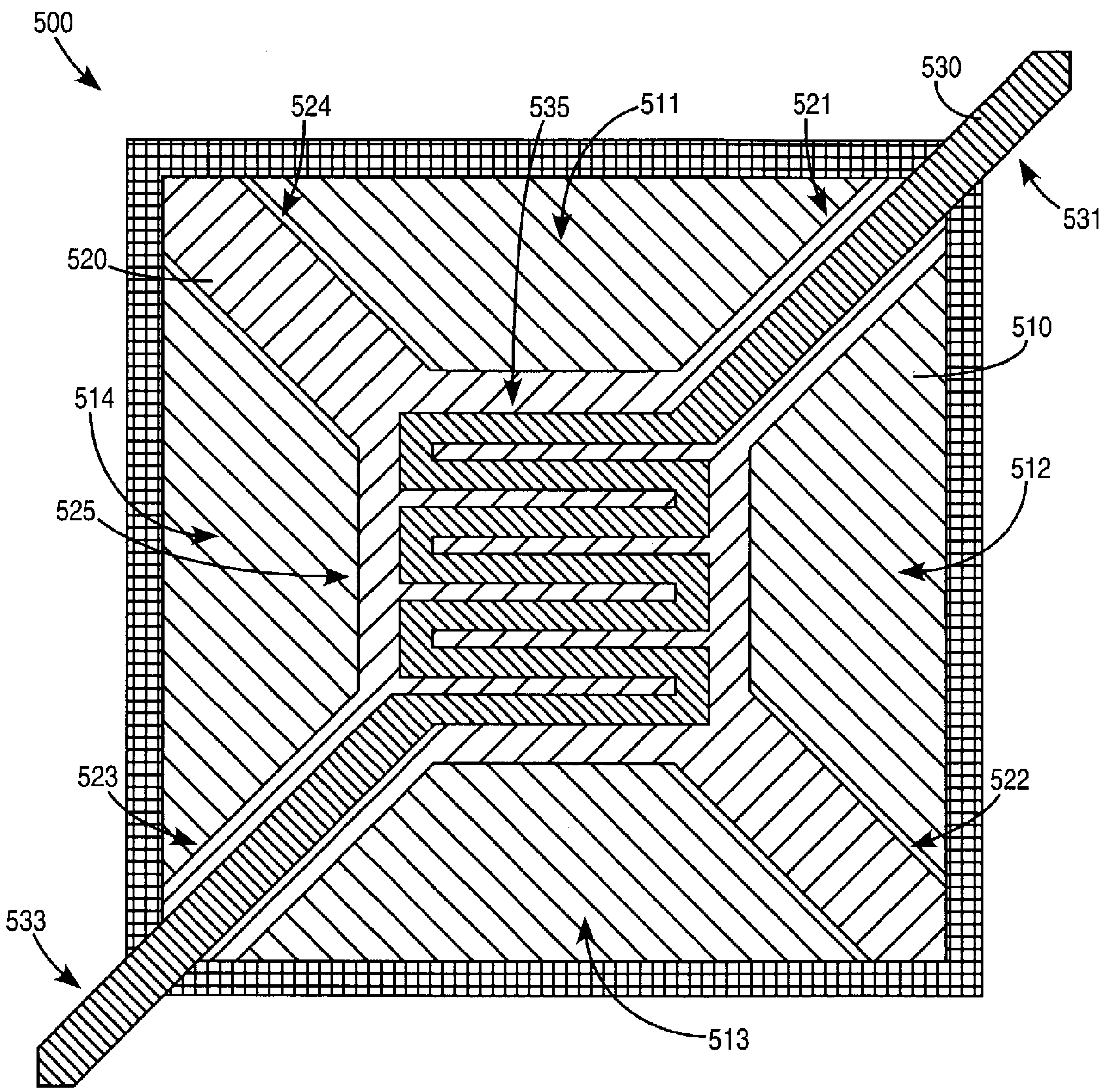
(57) ABSTRACT

A sensor comprises sensing material that changes volume when exposed to one or more target particles. The sensor also comprises a transducing platform comprising a piezoresistive component to sense change in volume of the sensing material. The sensing material is positioned over the piezoresistive component.



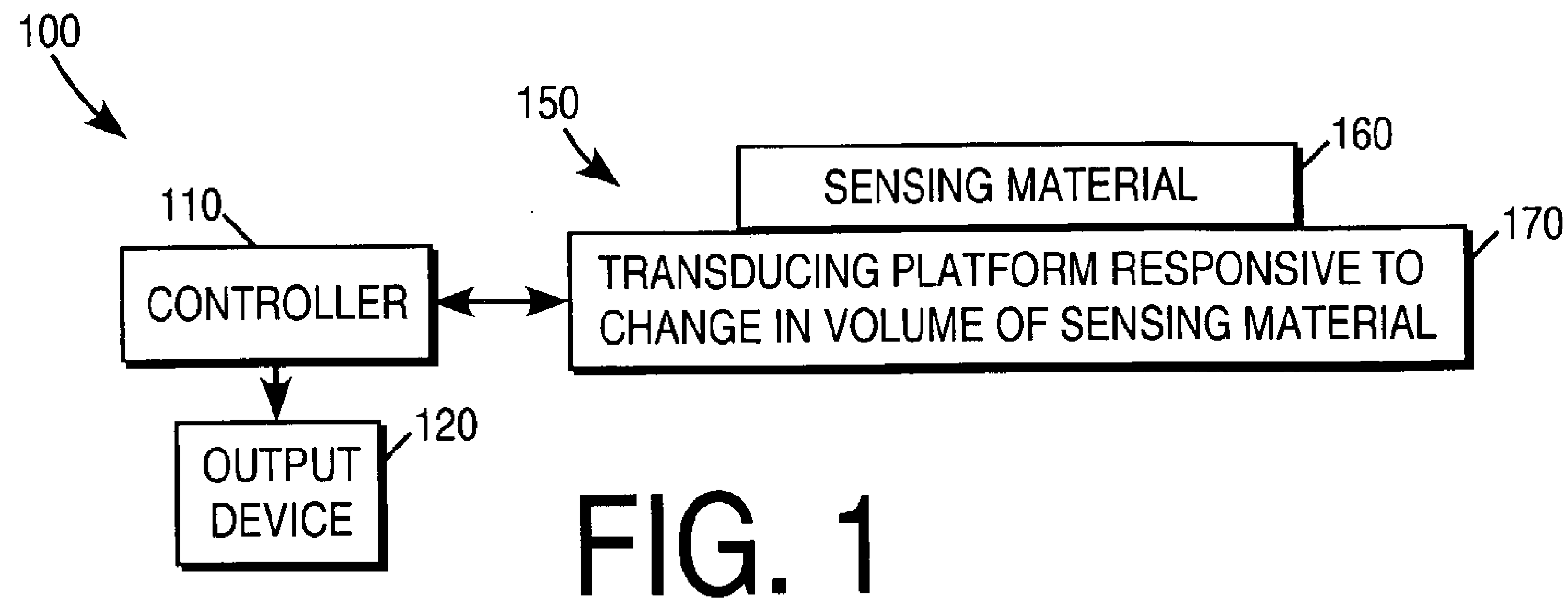


FIG. 1

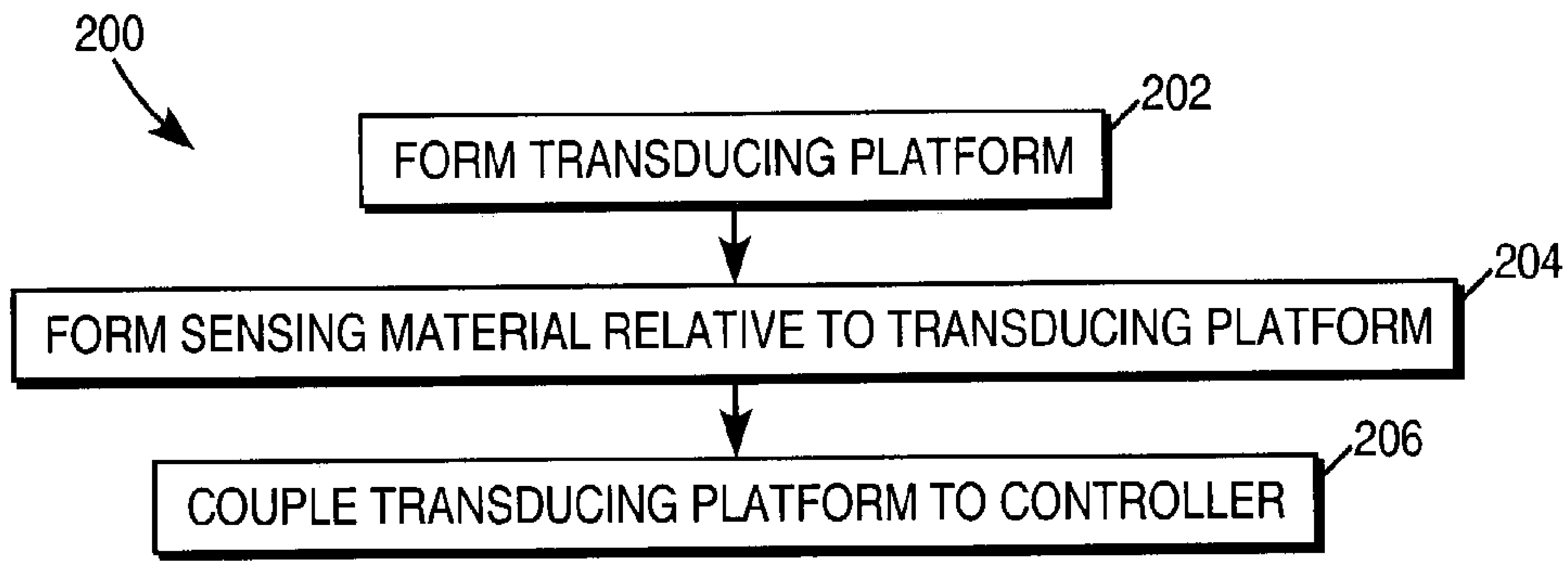


FIG. 2

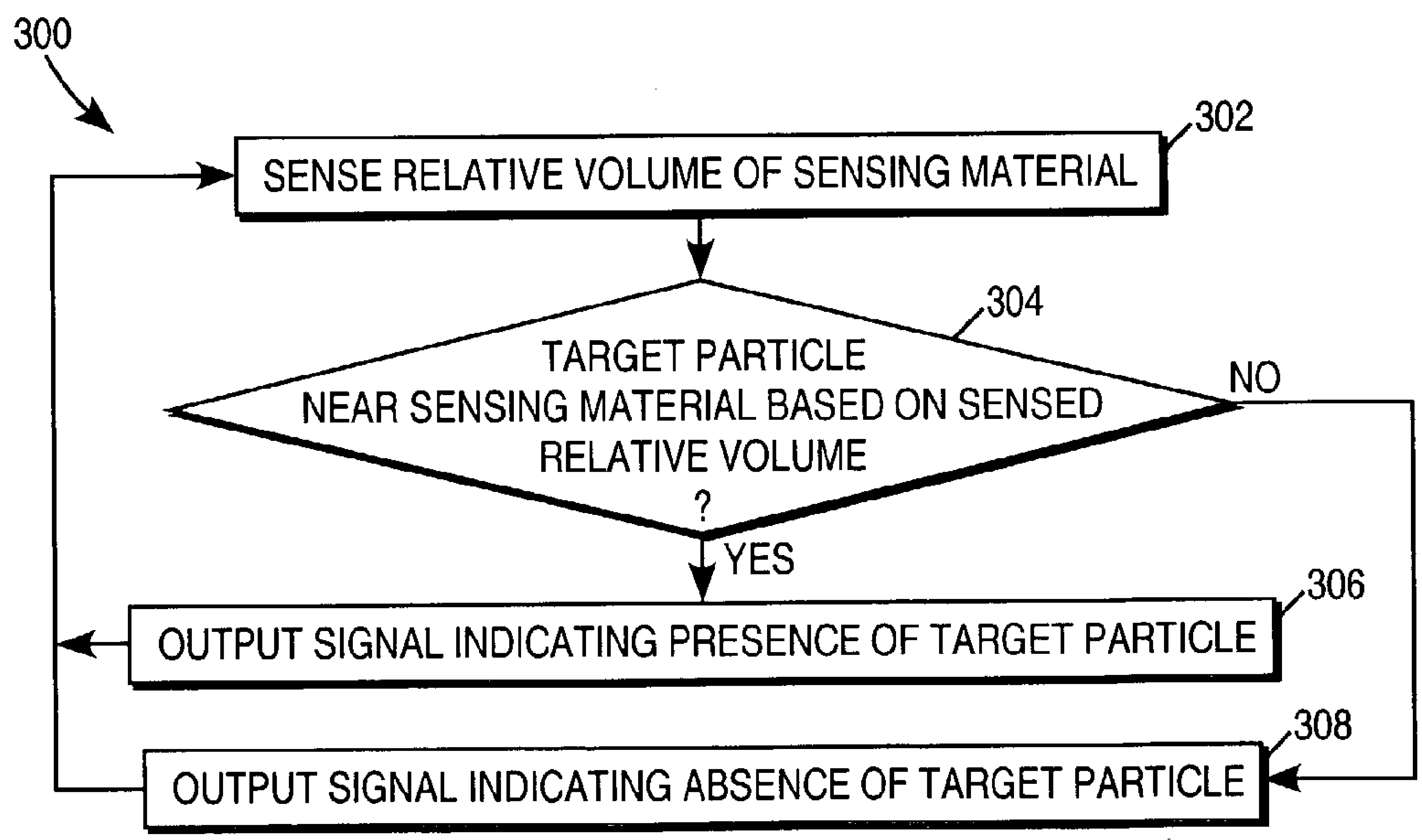


FIG. 3

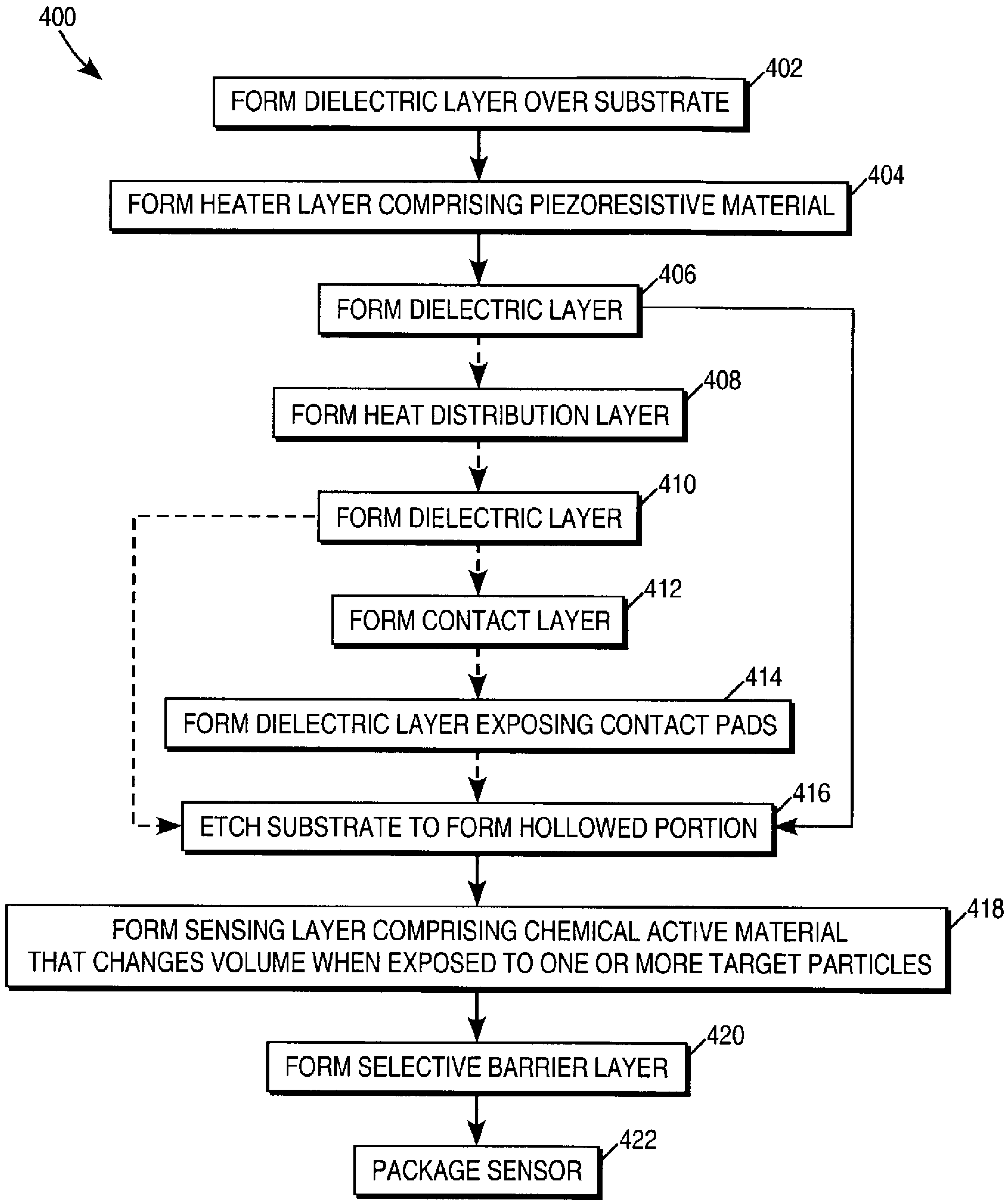

400
FORM DIELECTRIC LAYER OVER SUBSTRATE
402
FORM HEATER LAYER COMPRISING PIEZORESISTIVE MATERIAL
404
FORM DIELECTRIC LAYER
406
FORM HEAT DISTRIBUTION LAYER
408
FORM DIELECTRIC LAYER
410
FORM CONTACT LAYER
412
FORM DIELECTRIC LAYER EXPOSING CONTACT PADS
414
ETCH SUBSTRATE TO FORM HOLLOWED PORTION
416
FORM SENSING LAYER COMPRISING CHEMICAL ACTIVE MATERIAL THAT CHANGES VOLUME WHEN EXPOSED TO ONE OR MORE TARGET PARTICLES
418
FORM SELECTIVE BARRIER LAYER
420
PACKAGE SENSOR
422

FIG. 4

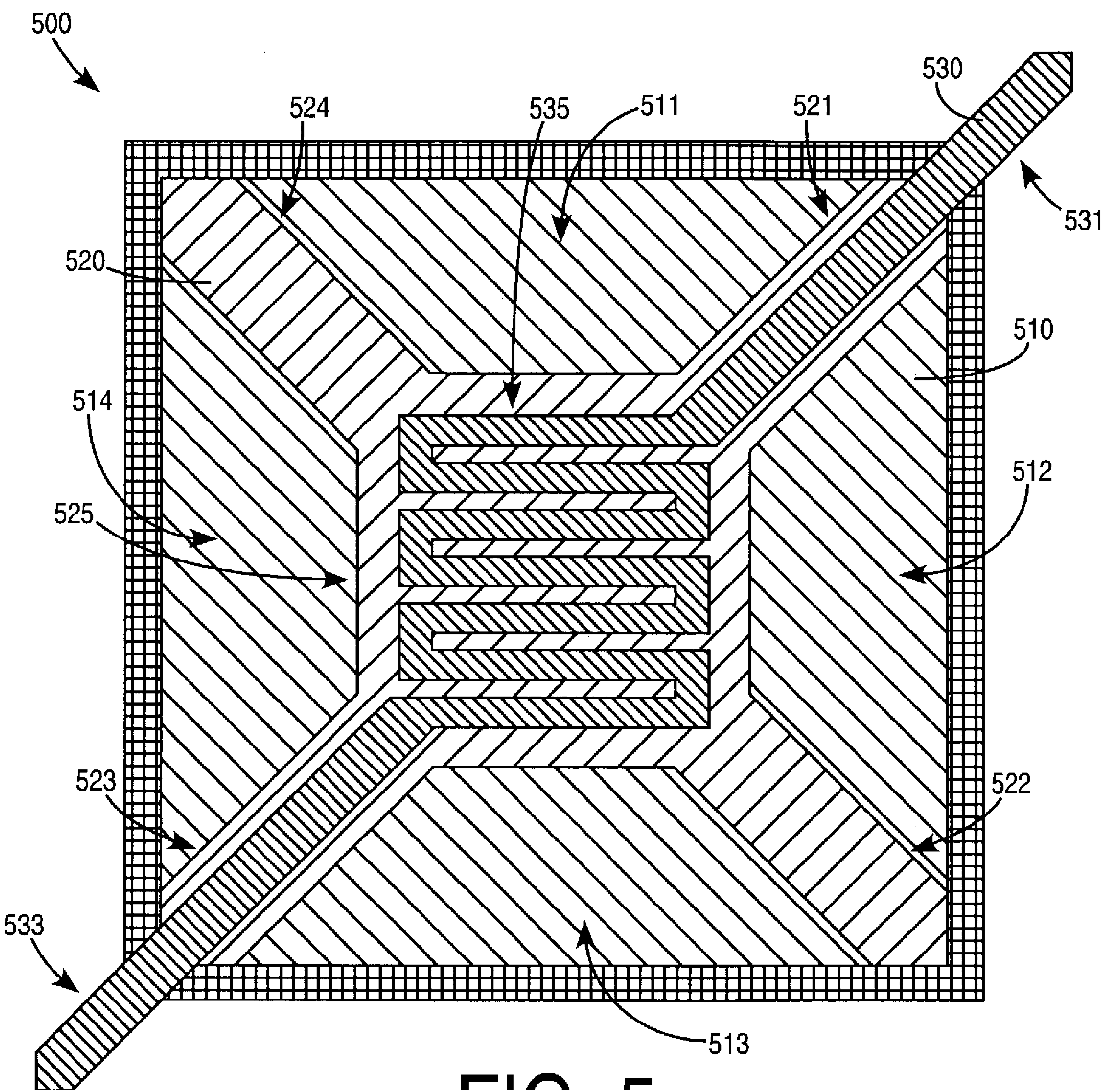


FIG. 5

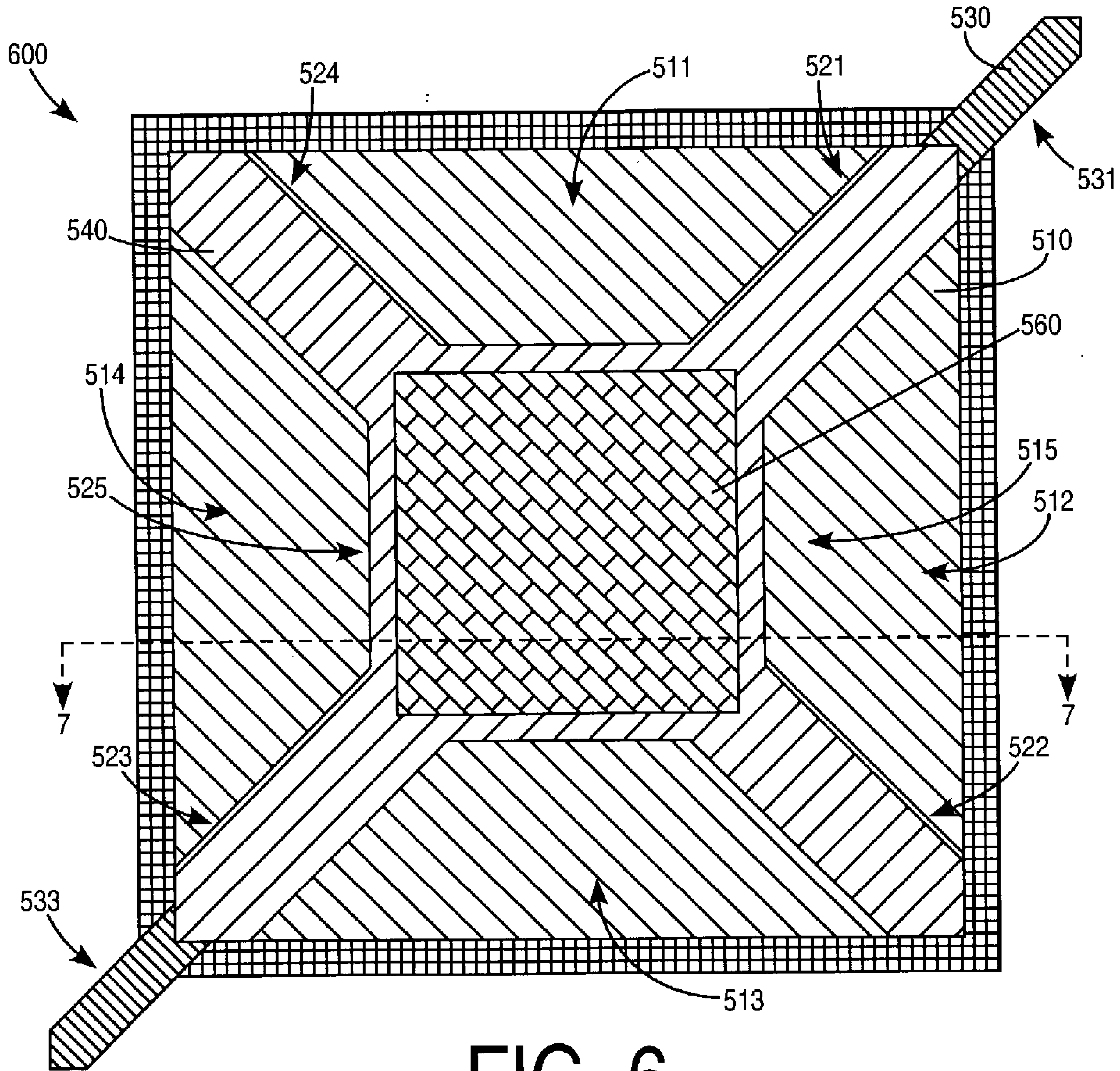

600
524
511
521
530
531
540
510
560
514
515
525
512
7
7
523
522
533
513

FIG. 6

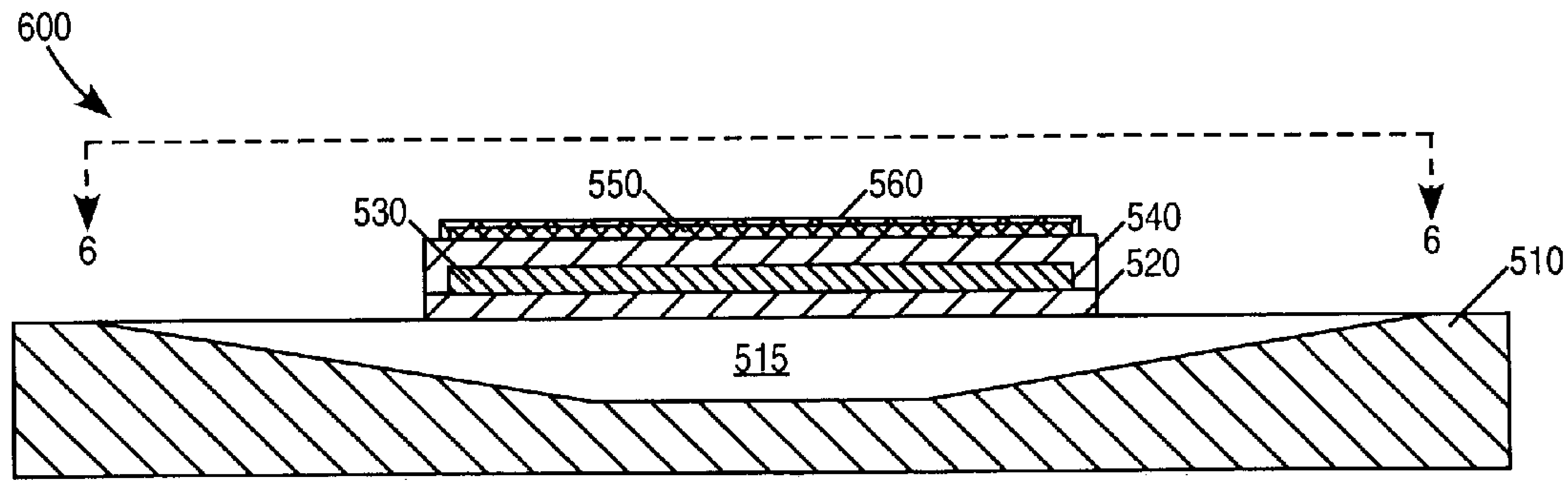

600
550
560
530
540
520
6
6
510
515

FIG. 7

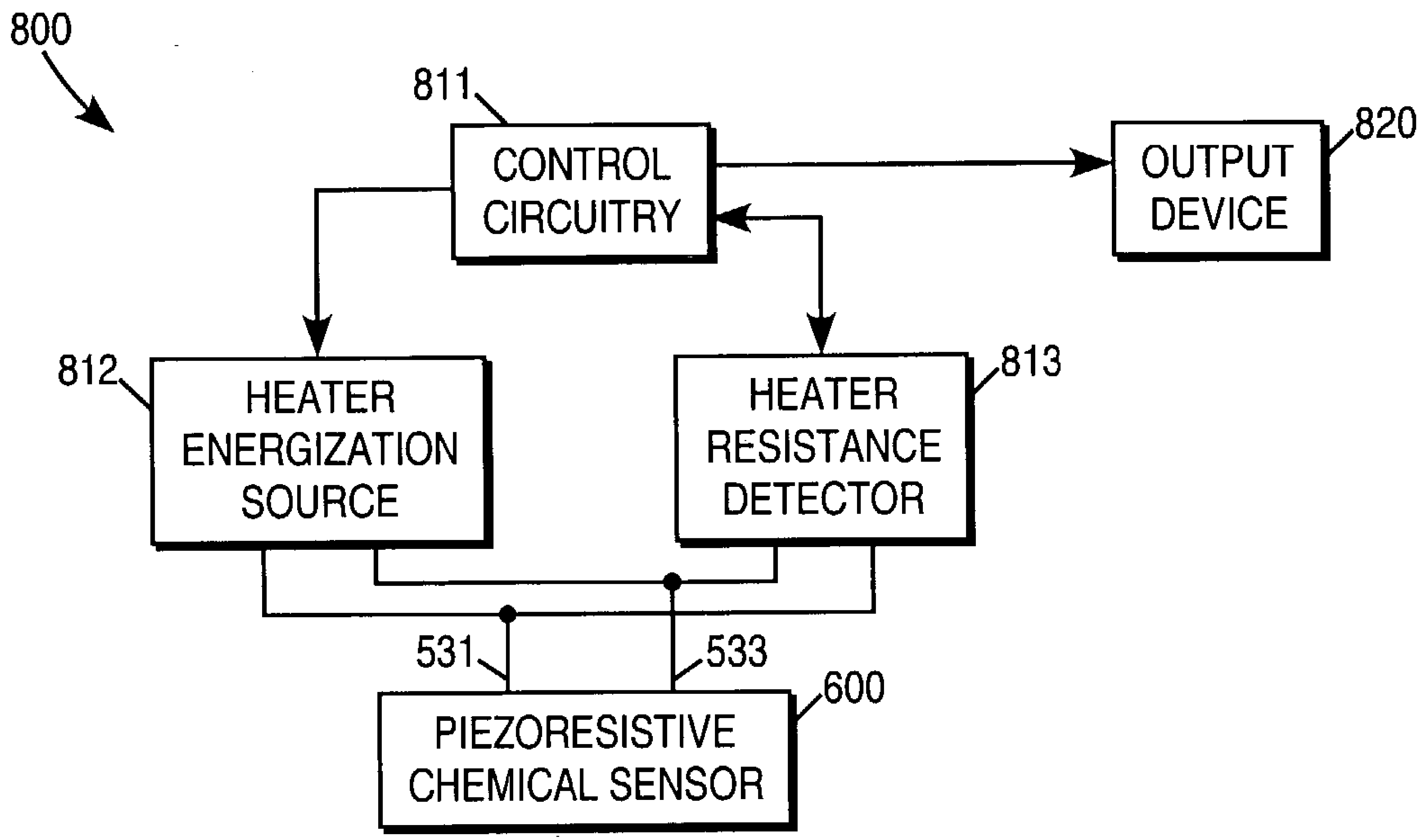

800
811
CONTROL CIRCUITRY
OUTPUT DEVICE
820
812
HEATER ENERGIZATION SOURCE
HEATER RESISTANCE DETECTOR
813
531
533
PIEZORESISTIVE CHEMICAL SENSOR
600

FIG. 8

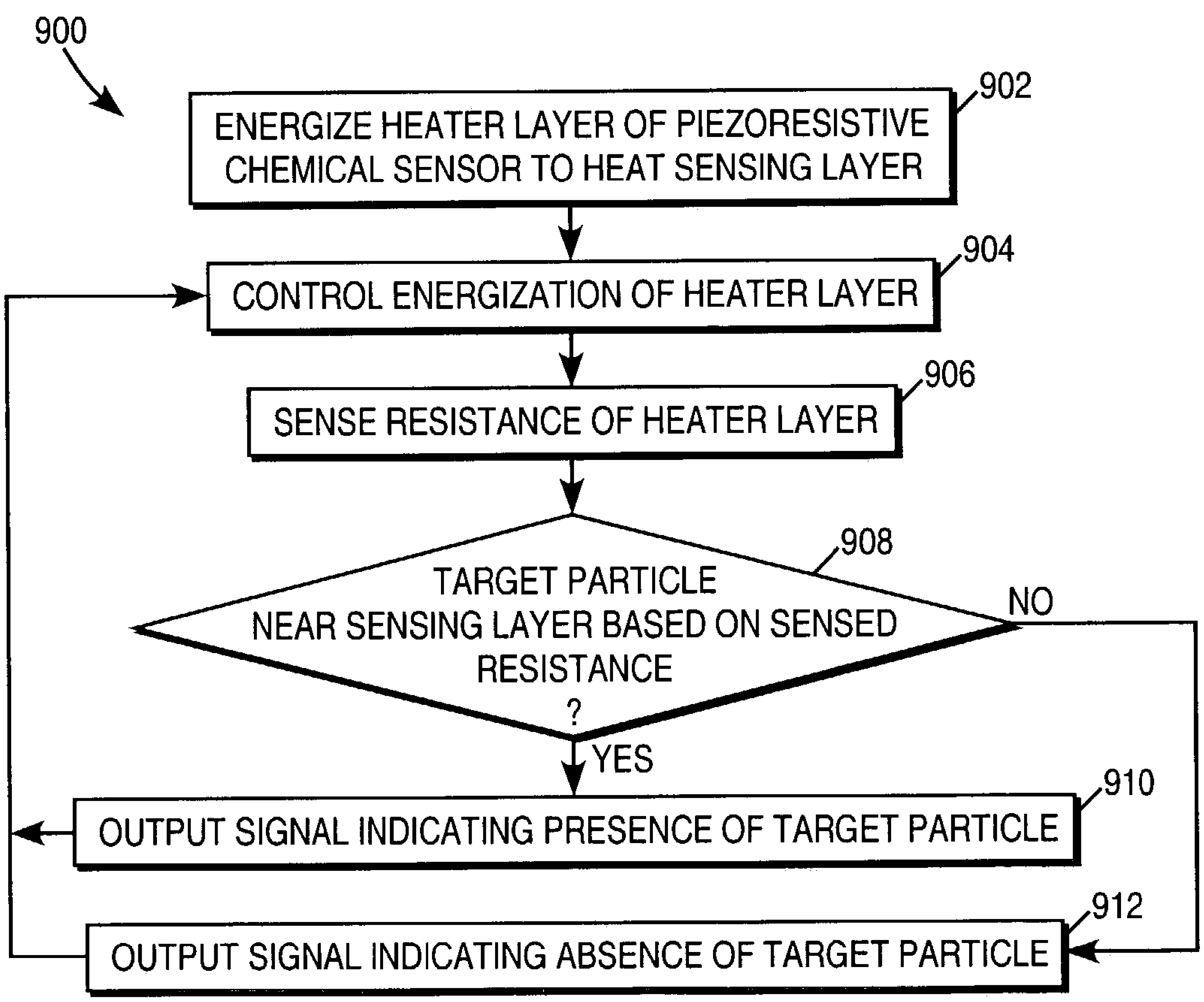
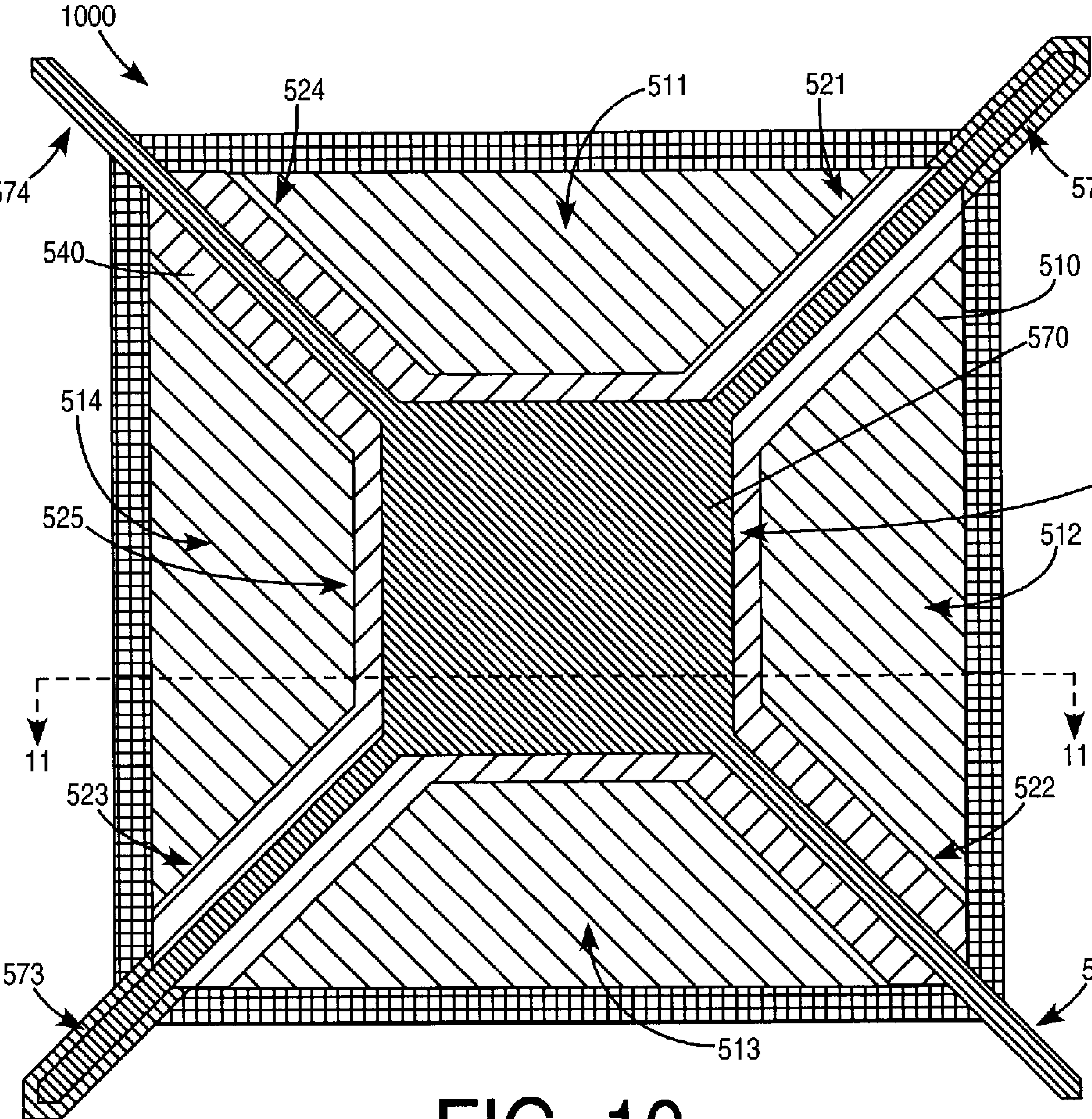
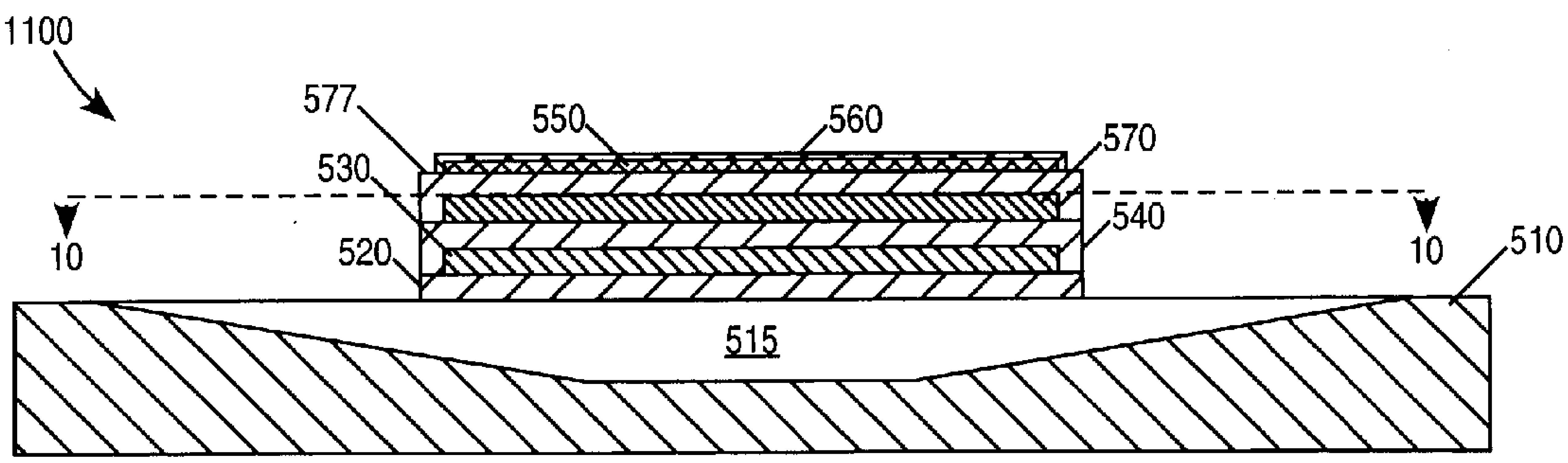

900
ENERGIZE HEATER LAYER OF PIEZORESISTIVE CHEMICAL SENSOR TO HEAT SENSING LAYER
902
CONTROL ENERGIZATION OF HEATER LAYER
904
SENSE RESISTANCE OF HEATER LAYER
906
TARGET PARTICLE NEAR SENSING LAYER BASED ON SENSED RESISTANCE ?
908
NO
YES
OUTPUT SIGNAL INDICATING PRESENCE OF TARGET PARTICLE
910
OUTPUT SIGNAL INDICATING ABSENCE OF TARGET PARTICLE
912

FIG. 9



1000
524
511
521
574
571
540
510
570
514
575
525
512
11
11
523
522
573
572
513

FIG. 10



1100
577
550
560
570
530
540
10
520
10
510
515

FIG. 11

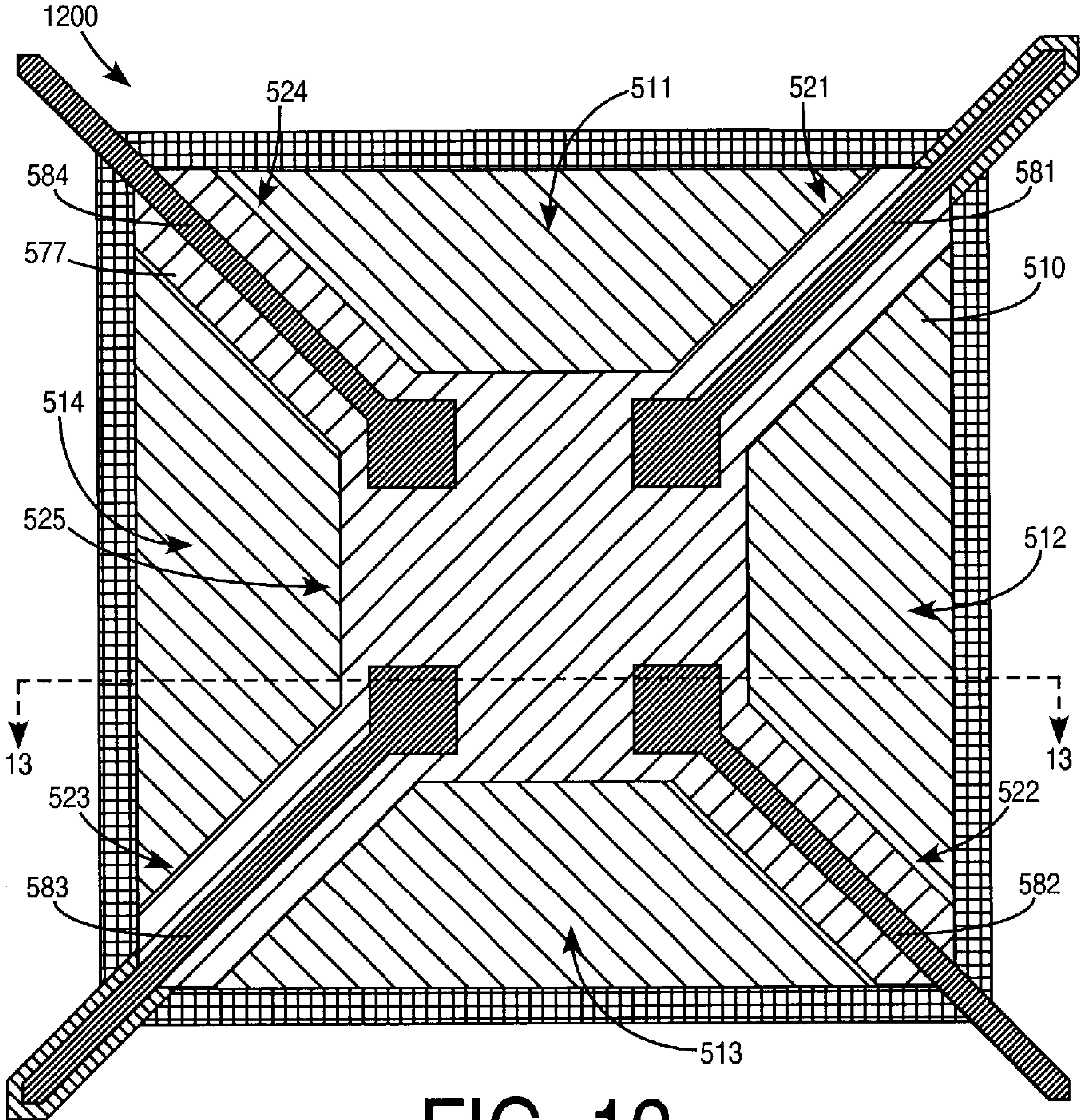

1200
524
511
521
584
581
577
510
514
525
512
13
13
523
522
583
582
513

FIG. 12

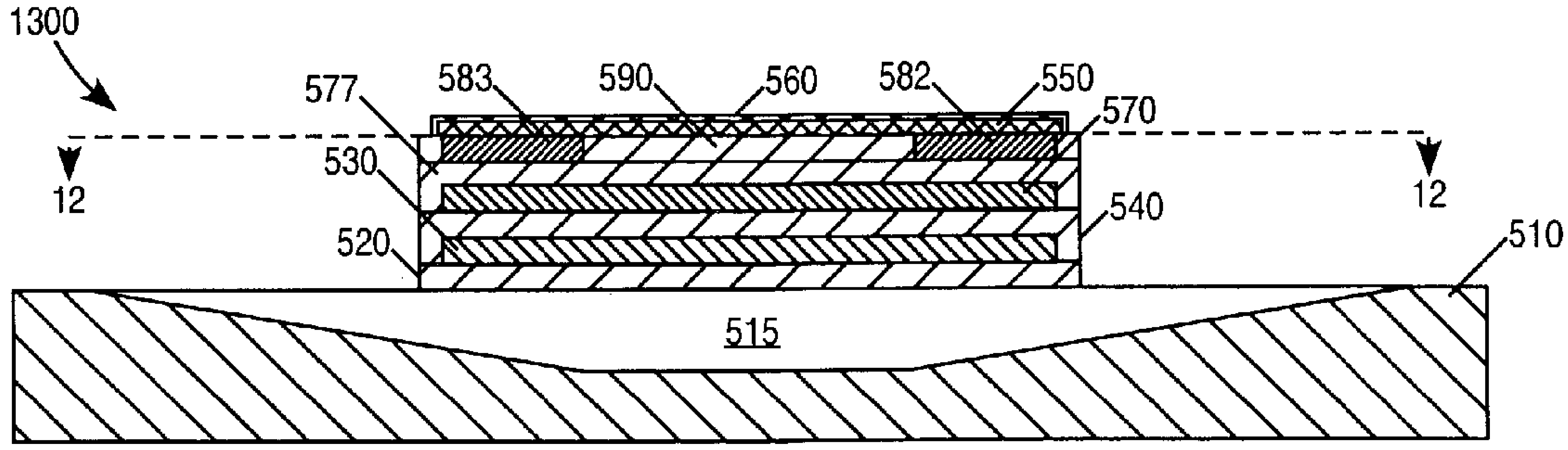

1300
577
583
590
560
582
550
570
12
530
12
540
520
510
515

FIG. 13

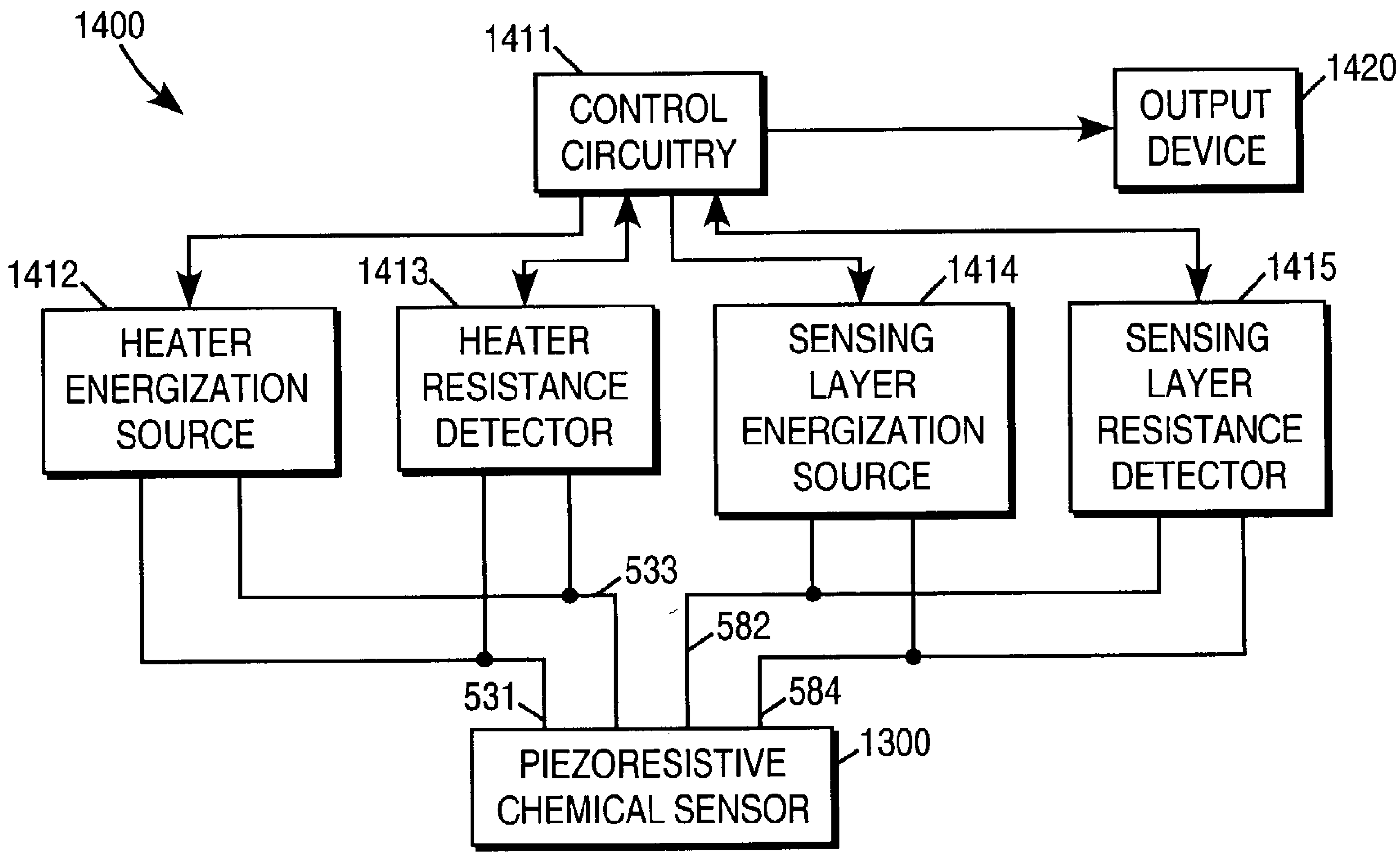

1400
1411
CONTROL CIRCUITRY
OUTPUT DEVICE
1420
1412
HEATER ENERGIZATION SOURCE
1413
HEATER RESISTANCE DETECTOR
1414
SENSING LAYER ENERGIZATION SOURCE
1415
SENSING LAYER RESISTANCE DETECTOR
533
582
531
584
1300
PIEZORESISTIVE CHEMICAL SENSOR

FIG. 14

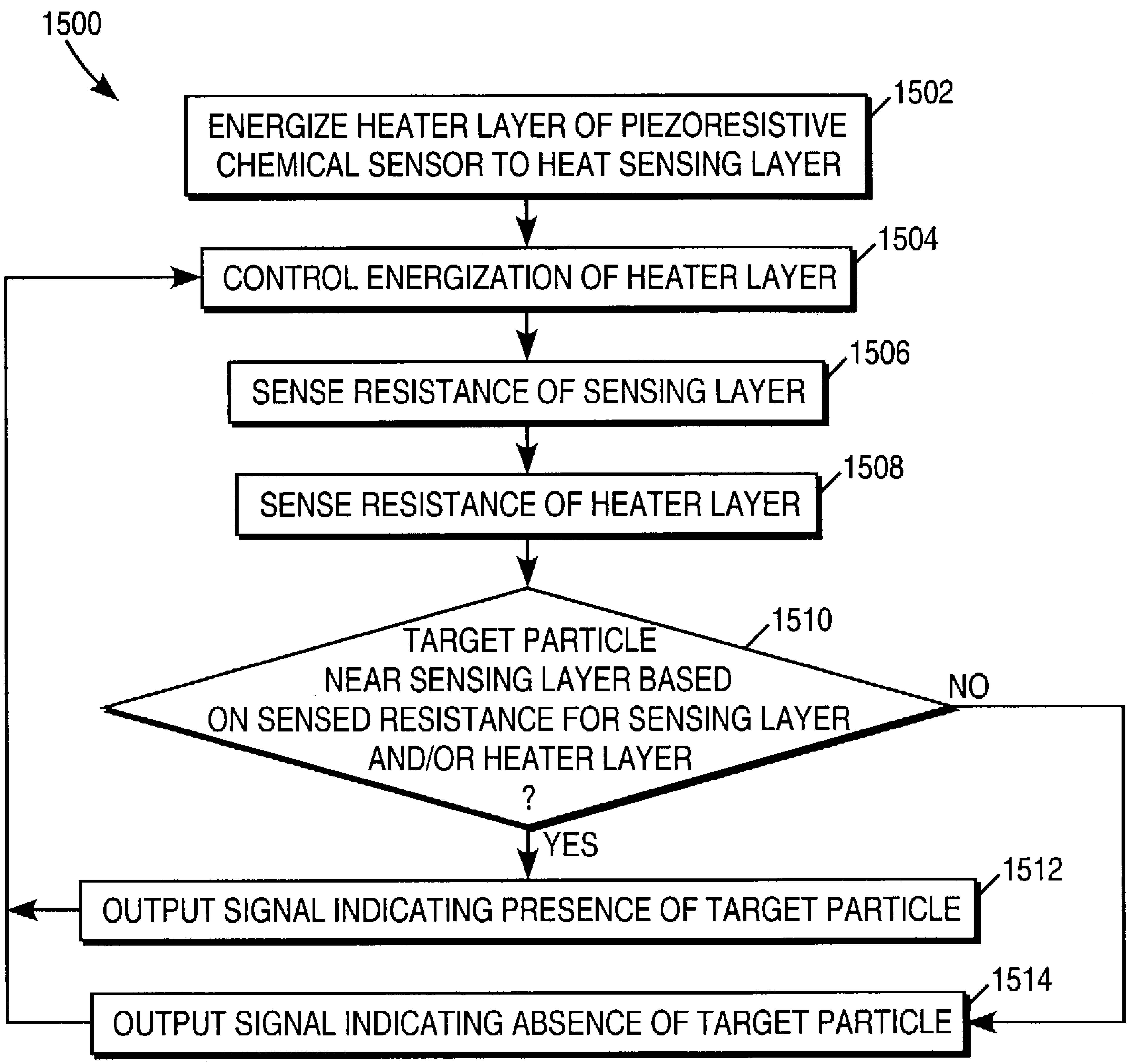

1500
ENERGIZE HEATER LAYER OF PIEZORESISTIVE CHEMICAL SENSOR TO HEAT SENSING LAYER
1502
CONTROL ENERGIZATION OF HEATER LAYER
1504
SENSE RESISTANCE OF SENSING LAYER
1506
SENSE RESISTANCE OF HEATER LAYER
1508
TARGET PARTICLE NEAR SENSING LAYER BASED ON SENSED RESISTANCE FOR SENSING LAYER AND/OR HEATER LAYER ?
1510
NO
YES
OUTPUT SIGNAL INDICATING PRESENCE OF TARGET PARTICLE
1512
OUTPUT SIGNAL INDICATING ABSENCE OF TARGET PARTICLE
1514

FIG. 15

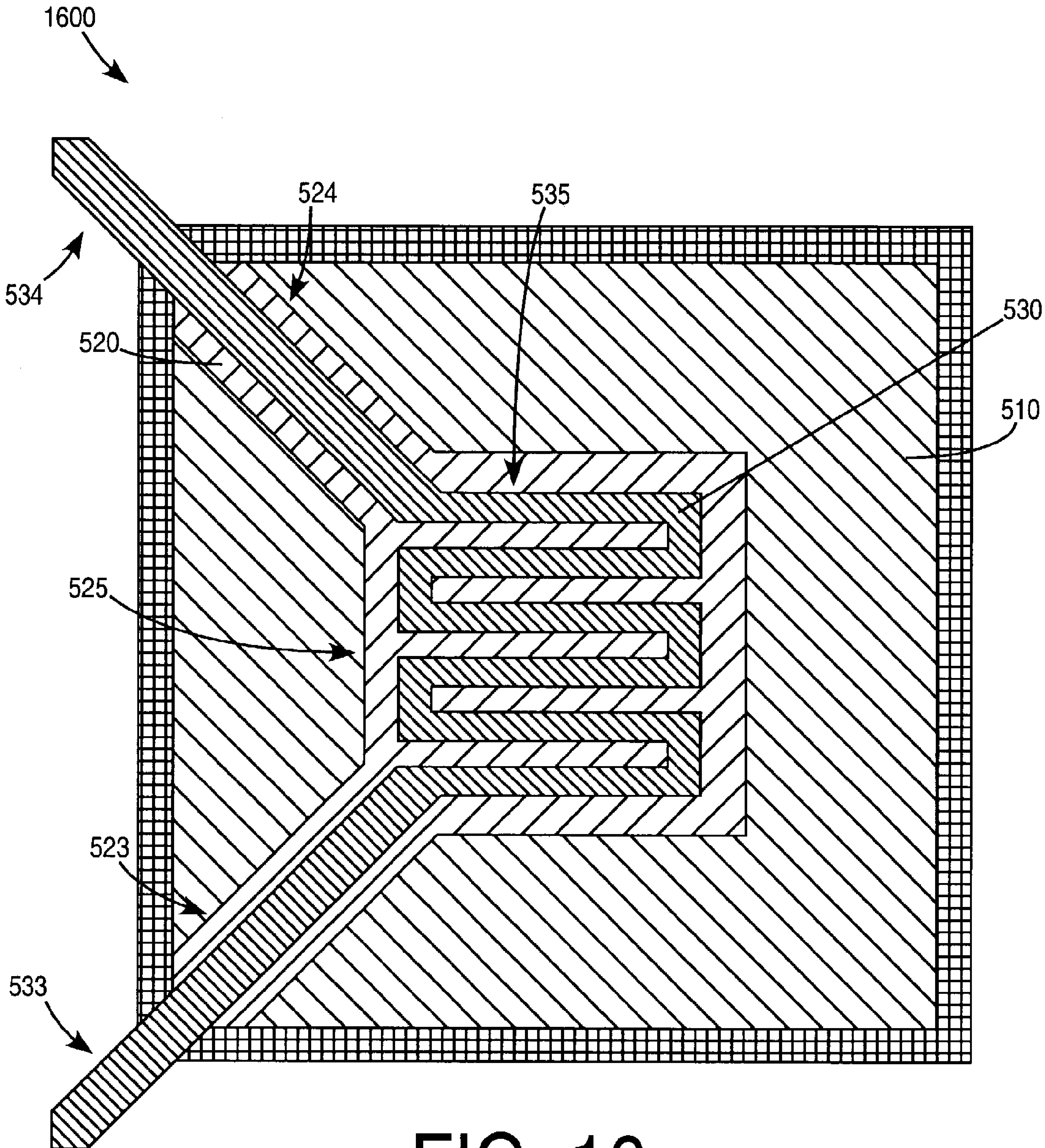


FIG. 16

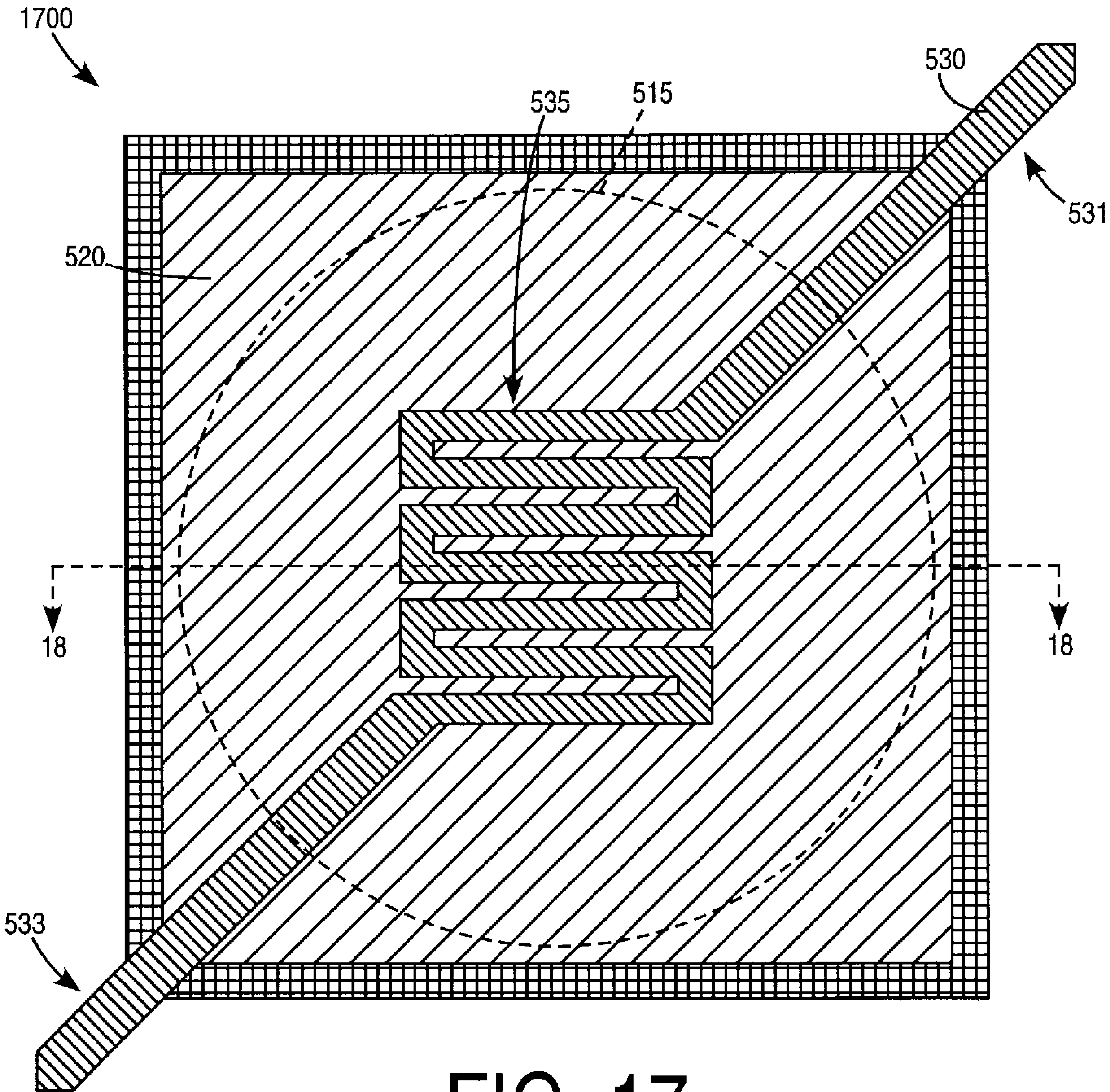

1700
530
535
515
531
520
18
18
533

FIG. 17

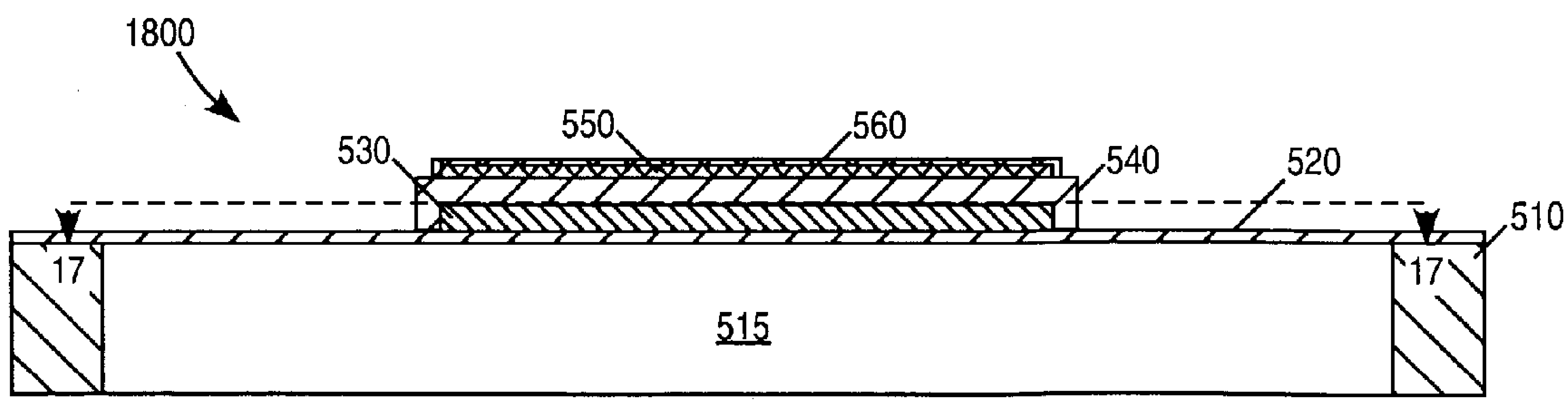

1800
550
560
530
540
520
510
17
17
515

FIG. 18

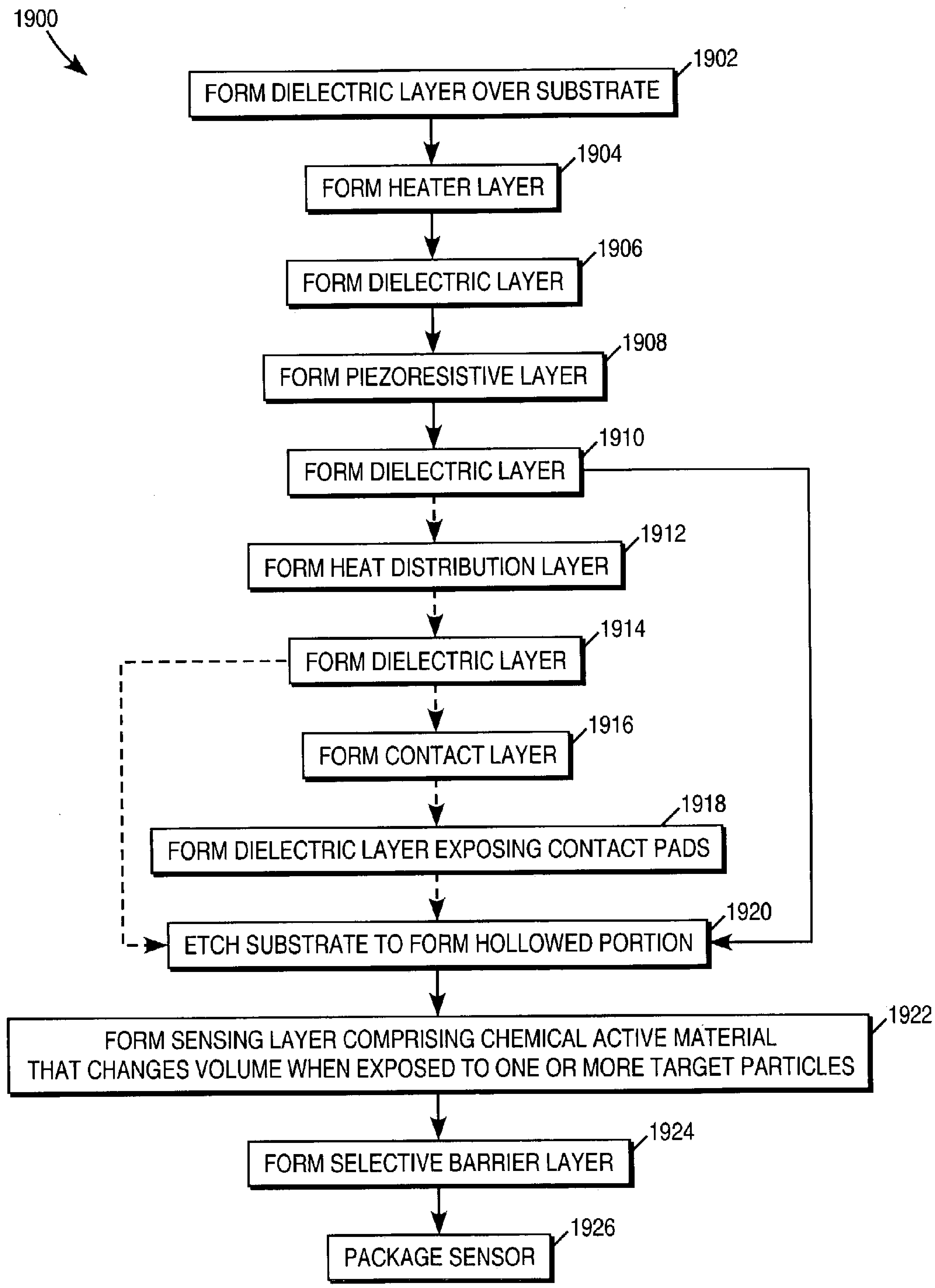

1900
FORM DIELECTRIC LAYER OVER SUBSTRATE
1902
FORM HEATER LAYER
1904
FORM DIELECTRIC LAYER
1906
FORM PIEZORESISTIVE LAYER
1908
FORM DIELECTRIC LAYER
1910
FORM HEAT DISTRIBUTION LAYER
1912
FORM DIELECTRIC LAYER
1914
FORM CONTACT LAYER
1916
FORM DIELECTRIC LAYER EXPOSING CONTACT PADS
1918
ETCH SUBSTRATE TO FORM HOLLOWED PORTION
1920
FORM SENSING LAYER COMPRISING CHEMICAL ACTIVE MATERIAL
THAT CHANGES VOLUME WHEN EXPOSED TO ONE OR MORE TARGET PARTICLES
1922
FORM SELECTIVE BARRIER LAYER
1924
PACKAGE SENSOR
1926

FIG. 19

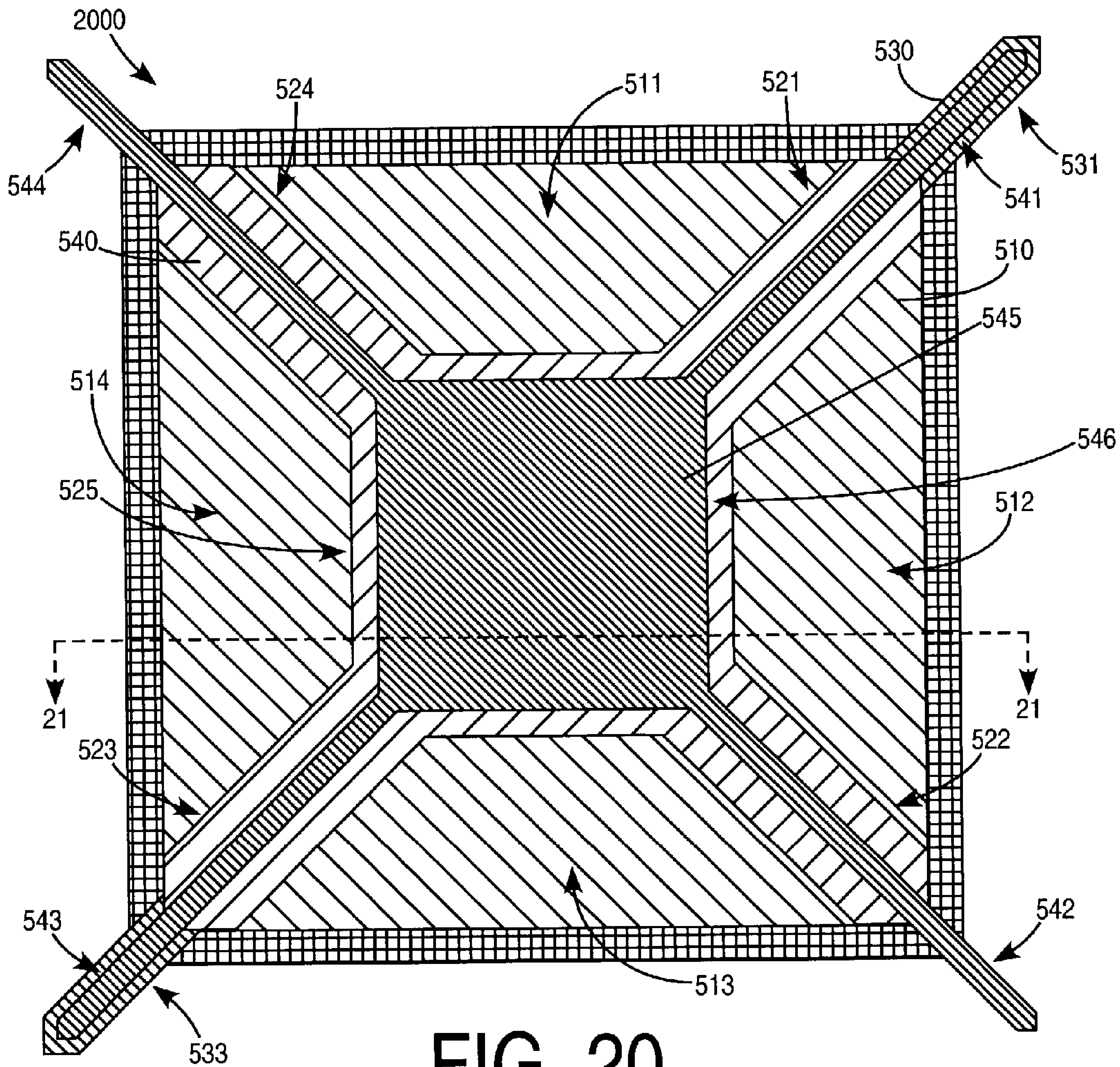

2000
524
511
521
530
531
544
541
540
510
545
514
546
525
512
21
21
523
522
543
542
513
533

FIG. 20

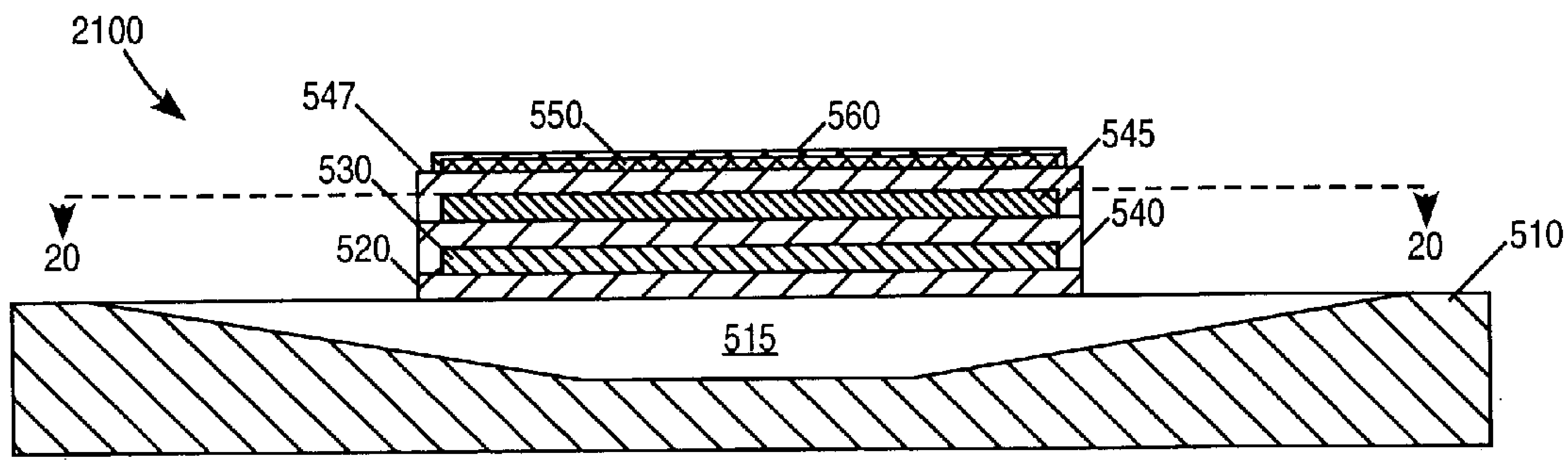

2100
547
550
560
545
530
540
20
520
20
510
515

FIG. 21

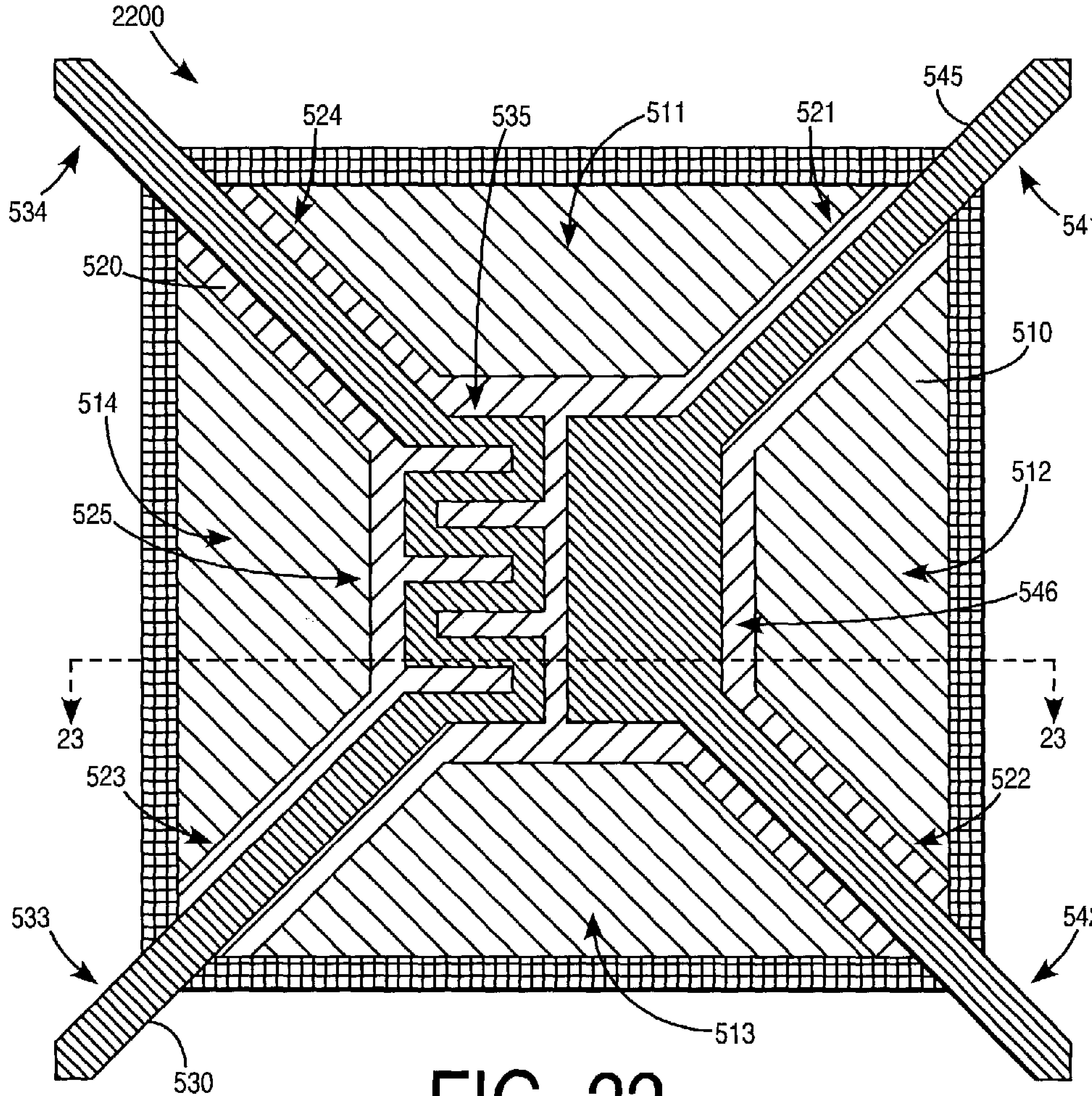

2200
524
535
511
521
545
534
541
520
510
514
512
525
546
23
23
523
522
533
542
513
530

FIG. 22

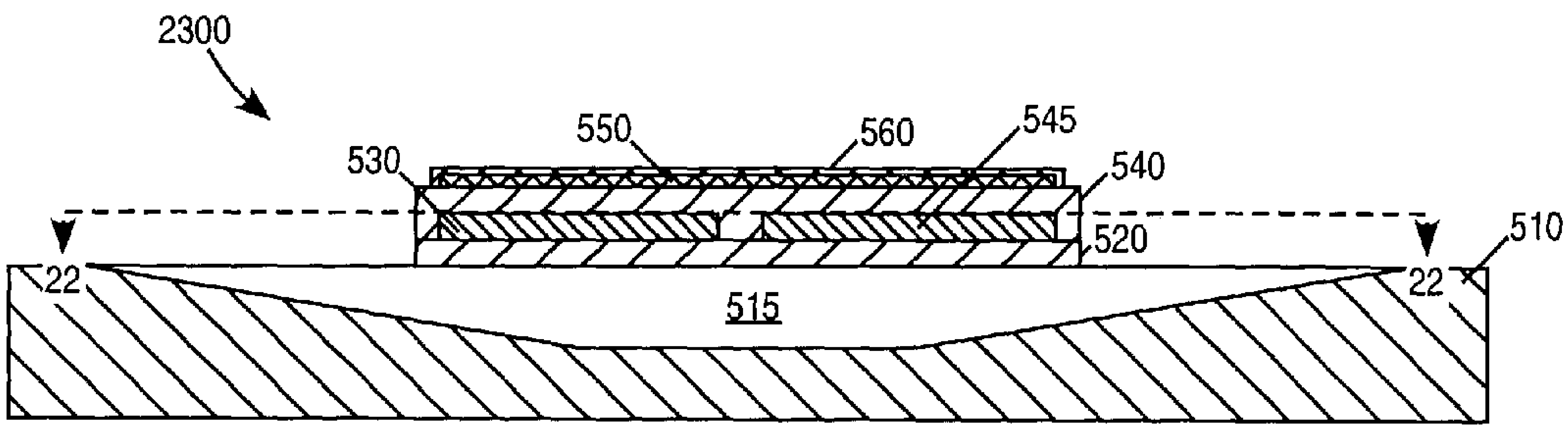

2300
550
560
545
530
540
520
510
22
22
515

FIG. 23

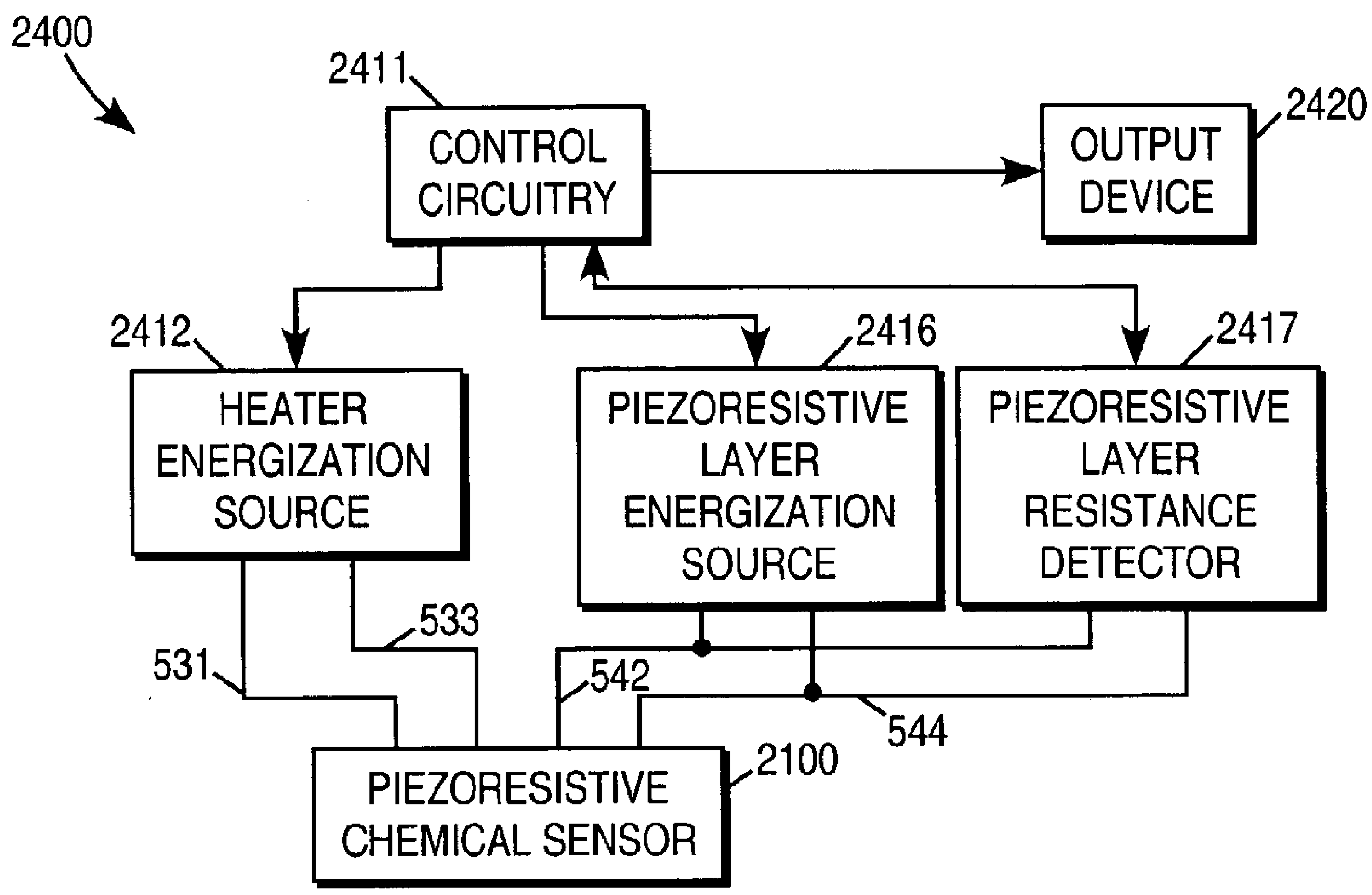

2400
2411
CONTROL CIRCUITRY
OUTPUT DEVICE
2420
2412
HEATER ENERGIZATION SOURCE
2416
PIEZORESISTIVE LAYER ENERGIZATION SOURCE
2417
PIEZORESISTIVE LAYER RESISTANCE DETECTOR
531
533
542
544
PIEZORESISTIVE CHEMICAL SENSOR
2100

FIG. 24

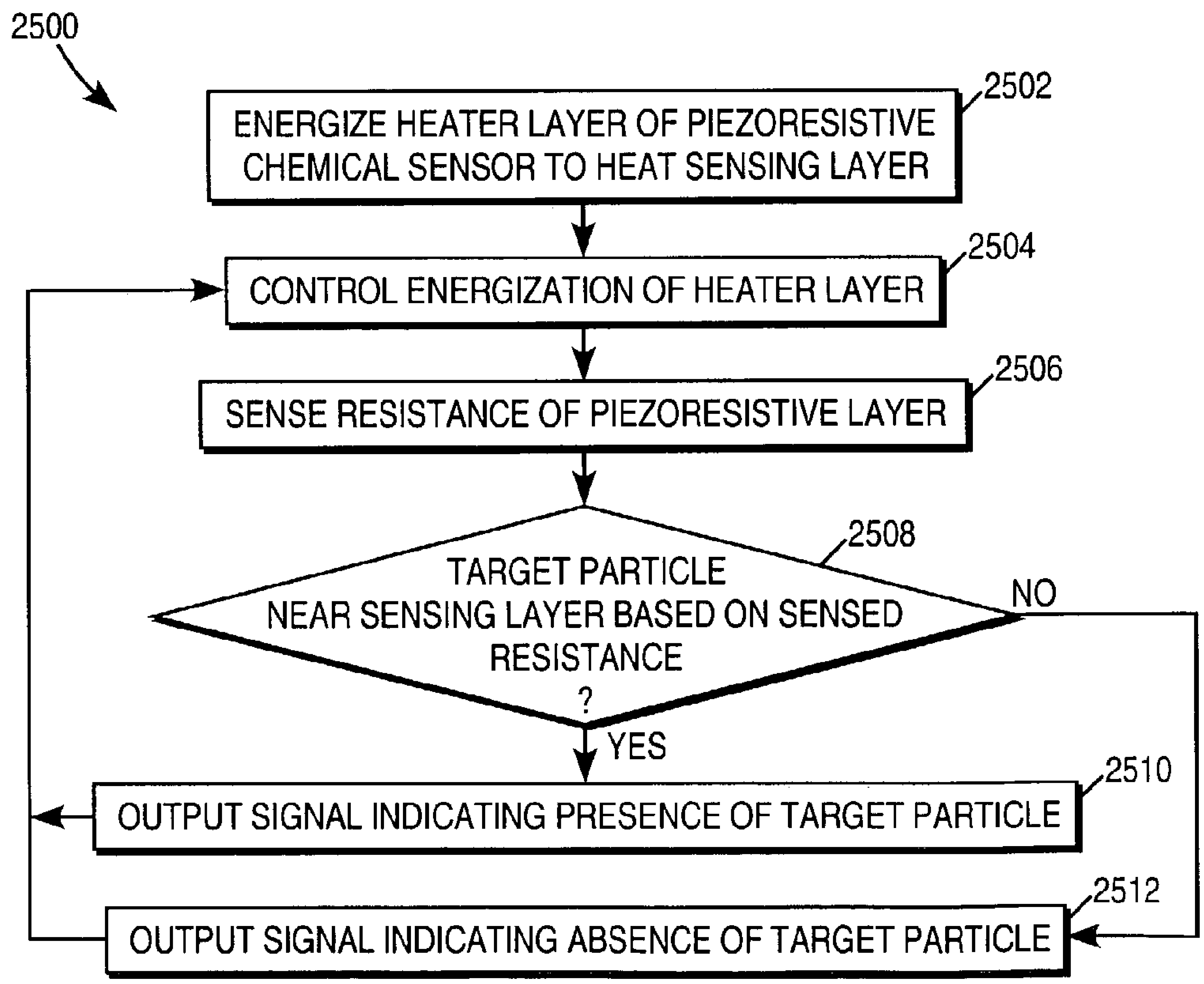

2500
ENERGIZE HEATER LAYER OF PIEZORESISTIVE CHEMICAL SENSOR TO HEAT SENSING LAYER
2502
CONTROL ENERGIZATION OF HEATER LAYER
2504
SENSE RESISTANCE OF PIEZORESISTIVE LAYER
2506
TARGET PARTICLE NEAR SENSING LAYER BASED ON SENSED RESISTANCE ?
2508
NO
YES
OUTPUT SIGNAL INDICATING PRESENCE OF TARGET PARTICLE
2510
OUTPUT SIGNAL INDICATING ABSENCE OF TARGET PARTICLE
2512

FIG. 25

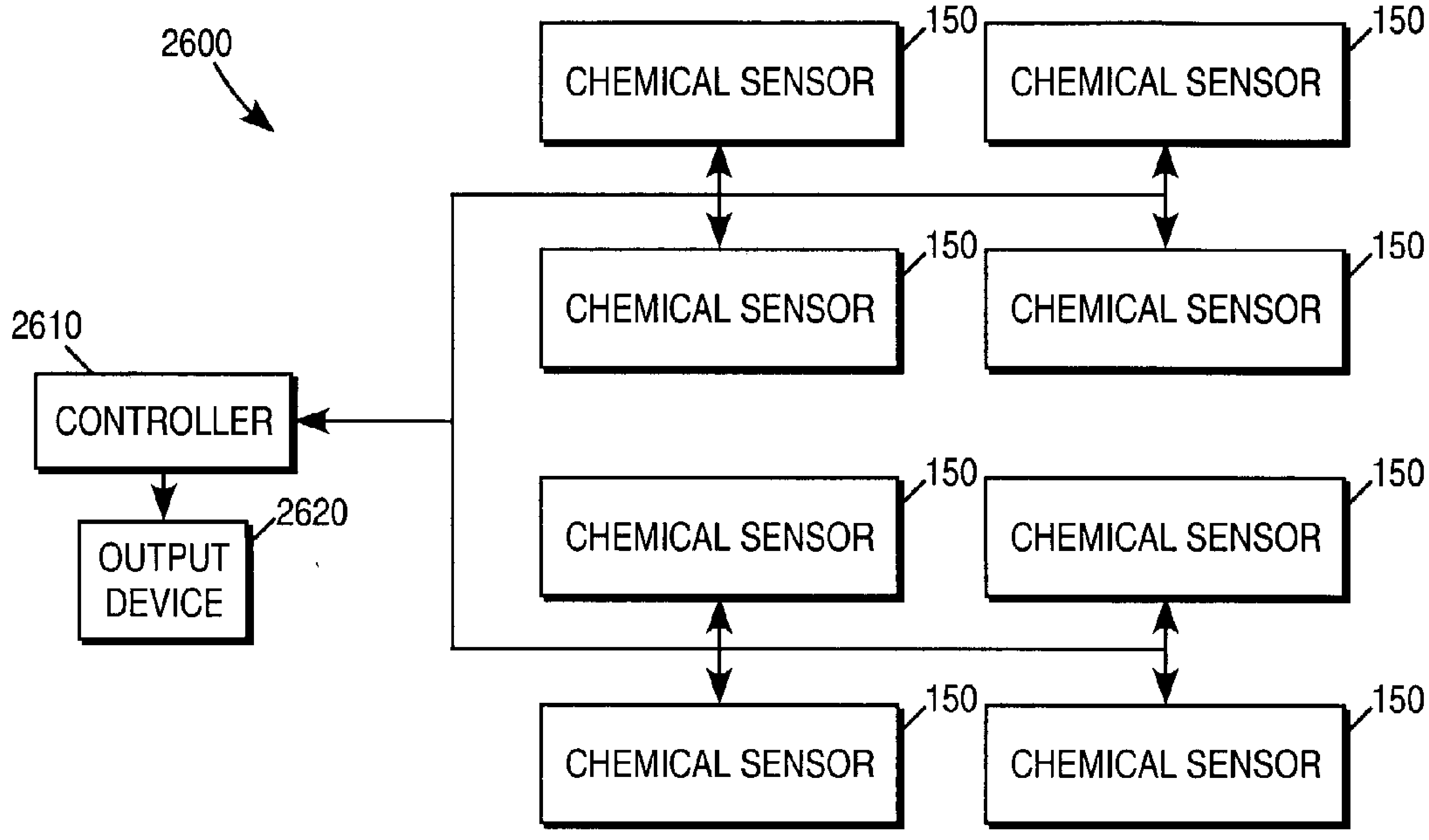

2600
2610
CONTROLLER
2620
OUTPUT DEVICE
CHEMICAL SENSOR
150
CHEMICAL SENSOR
150
CHEMICAL SENSOR
150
CHEMICAL SENSOR
150
CHEMICAL SENSOR
150
CHEMICAL SENSOR
150
CHEMICAL SENSOR
150
CHEMICAL SENSOR
150

FIG. 26

CHEMICAL SENSOR RESPONSIVE TO CHANGE IN VOLUME OF MATERIAL EXPOSED TO TARGET PARTICLE

GOVERNMENT RIGHTS

[0001] One or more embodiments described in this patent application were conceived with U.S. Government support under Contract No. DE-FC36-99GO10451. The U.S. Government has certain rights in this patent application.

TECHNICAL FIELD

[0002] One or more embodiments described in this patent application relate to the field of chemical sensors.

BACKGROUND ART

[0003] Chemical sensors may be used for a wide variety of purposes. Hydrogen (H_2) sensors, for example, may be used to help detect hydrogen gas leaks and to help monitor and control hydrogen-based processes for fuel cells, for example. Carbon monoxide (CO) sensors may be used to help detect unsafe levels of carbon monoxide in a home or garage, for example. Propane sensors may be used in conjunction with gas grills. Industrial sensors may be used to help detect unsafe levels of chemicals or toxins at chemical plants, coal mines, or semiconductor fabrication facilities, for example.

SUMMARY

[0004] One or more embodiments of a sensor comprise sensing material that changes volume when exposed to one or more target particles and comprise a transducing platform comprising a piezoresistive component to sense change in volume of the sensing material. The sensing material is positioned over the piezoresistive component.

[0005] One or more embodiments of another sensor comprise a first layer comprising a piezoresistive material to sense change in volume of one or more layers over the first layer and comprise a second layer over the first layer. The second layer comprises a material that changes volume when exposed to one or more target particles.

[0006] One or more embodiments of an apparatus comprise sensing material that changes volume when exposed to one or more target particles, means for sensing change in volume of the sensing material, and means for controlling temperature of the sensing material.

[0007] One or more embodiments of a sensing device comprise a sensor and a controller. The sensor comprises a piezoresistive layer and sensing material over the piezoresistive layer. The sensing material changes volume when exposed to one or more target particles. The controller is to sense a resistance of the piezoresistive layer.

[0008] One or more embodiments of a method comprise forming over a substrate a first layer comprising a piezoresistive material to sense change in volume of one or more layers over the first layer and comprise forming over the first layer a second layer comprising a material that changes volume when exposed to a target particle.

[0009] One or more embodiments of another method comprise sensing a resistance of a piezoresistive layer with sensing material over the piezoresistive layer. The sensing material changes volume when exposed to one or more target particles. The one or more embodiments also comprise identifying whether a target particle is near the sensing material based on the sensed resistance of the piezoresistive layer.

[0010] One or more embodiments of another sensing device comprise an array of sensors and a controller. At least one sensor comprises a piezoresistive layer and sensing material over the piezoresistive layer. The sensing material changes volume when exposed to one or more target particles. The controller is coupled to the array of sensors to sense a resistance of the piezoresistive layer of at least one sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] One or more embodiments are illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

[0012] **FIG. 1** illustrates, for one embodiment, a block diagram of a sensing device comprising a chemical sensor responsive to change in volume of material exposed to a target particle;

[0013] **FIG. 2** illustrates, for one embodiment, a flow diagram to form a sensing device comprising a chemical sensor responsive to change in volume of material exposed to a target particle;

[0014] **FIG. 3** illustrates, for one embodiment, a flow diagram to use a chemical sensor responsive to change in volume of material exposed to a target particle;

[0015] **FIG. 4** illustrates a flow diagram summarizing embodiments of techniques to form a piezoresistive chemical sensor;

[0016] **FIG. 5** illustrates, for one embodiment, a plan view of a microhotplate structure for a piezoresistive chemical sensor;

[0017] **FIG. 6** illustrates, for one embodiment, a plan view of a piezoresistive chemical sensor having a microhotplate structure;

[0018] **FIG. 7** illustrates, for one embodiment, a cross-sectional view of the piezoresistive chemical sensor of **FIG. 6**;

[0019] **FIG. 8** illustrates, for one embodiment, a block diagram of a sensing device comprising a piezoresistive chemical sensor;

[0020] **FIG. 9** illustrates, for one embodiment, a flow diagram to use a piezoresistive chemical sensor to sense a target particle;

[0021] **FIG. 10** illustrates, for one embodiment, a plan view of a microhotplate structure having a heat distribution layer for a piezoresistive chemical sensor;

[0022] **FIG. 11** illustrates, for one embodiment, a cross-sectional view of a piezoresistive chemical sensor having a heat distribution layer;

[0023] **FIG. 12** illustrates, for one embodiment, a plan view of a microhotplate structure having a contact layer for a piezoresistive chemical sensor;

[**0024**] **FIG. 13** illustrates, for one embodiment, a cross-sectional view of a piezoresistive chemical sensor having a contact layer;

[**0025**] **FIG. 14** illustrates, for one embodiment, a block diagram of a sensing device comprising a piezoresistive chemical sensor having a contact layer;

[**0026**] **FIG. 15** illustrates, for one embodiment, a flow diagram to use a piezoresistive chemical sensor having a contact layer to sense a target particle;

[**0027**] **FIG. 16** illustrates, for one embodiment, a plan view of a microcantilever structure for a piezoresistive chemical sensor;

[**0028**] **FIG. 17** illustrates, for one embodiment, a plan view of a diaphragm structure for a piezoresistive chemical sensor;

[**0029**] **FIG. 18** illustrates, for one embodiment, a cross-sectional view of a piezoresistive chemical sensor having a diaphragm structure;

[**0030**] **FIG. 19** illustrates a flow diagram summarizing embodiments of techniques to form a piezoresistive chemical sensor having a piezoresistive layer separate from a heater layer;

[**0031**] **FIG. 20** illustrates, for one embodiment, a plan view of a microhotplate structure having a piezoresistive layer separate from a heater layer for a piezoresistive chemical sensor;

[**0032**] **FIG. 21** illustrates, for one embodiment, a cross-sectional view of a piezoresistive chemical sensor having a piezoresistive layer separate from a heater layer;

[**0033**] **FIG. 22** illustrates, for another embodiment, a plan view of a microhotplate structure having a piezoresistive layer separate from a heater layer for a piezoresistive chemical sensor;

[**0034**] **FIG. 23** illustrates, for another embodiment, a cross-sectional view of a piezoresistive chemical sensor having a piezoresistive layer separate from a heater layer;

[**0035**] **FIG. 24** illustrates, for one embodiment, a block diagram of a sensing device comprising a piezoresistive chemical sensor having a piezoresistive layer separate from a heater layer;

[**0036**] **FIG. 25** illustrates, for one embodiment, a flow diagram to use a piezoresistive chemical sensor having a piezoresistive layer separate from a heater layer to sense a target particle; and

[**0037**] **FIG. 26** illustrates, for one embodiment, a block diagram of a sensing device comprising an array of chemical sensors at least one of which is responsive to change in volume of material exposed to a target particle.

DETAILED DESCRIPTION

[**0038**] The following detailed description sets forth an embodiment or embodiments for a chemical sensor responsive to change in volume of material exposed to a target particle.

[**0039**] **FIG. 1** illustrates, for one embodiment, a sensing device **100**. Sensing device **100** may be used to sense any suitable target particle in any suitable environment for any suitable purpose. Sensing device **100** comprises a controller **110** and a chemical sensor **150** coupled to controller **110**.

[**0040**] Sensor **150** comprises sensing material **160** that changes volume when exposed to one or more target particles. Sensor **150** also comprises a transducing platform **170** responsive to change in volume of sensing material **160**. Sensor **150** for one embodiment is integrated.

[**0041**] Controller **110** may be coupled to transducing platform **170** to sense the presence of a target particle in an environment near sensing material **160**. Controller **110** for one embodiment may also be coupled to or in wireless communication with an output device **120** to output to output device **120** a signal indicating the presence of a target particle near sensing material **160**. Output device **120** may or may not be a component of sensing device **100**. At least a portion of controller **110** and/or output device **120** may be local to or remote from sensor **150**. Output device **120** may be local to or remote from controller **110**.

[**0042**] **FIG. 2** illustrates, for one embodiment, a flow diagram **200** to form sensing device **100**.

[**0043**] For block **202** of **FIG. 2**, transducing platform **170** is formed. Transducing platform **170** may be formed to sense change in volume of sensing material **160** in any suitable manner. Transducing platform **170** for one embodiment may comprise a piezoresistive component to sense change in volume of sensing material **160** through change in resistance of the piezoresistive component due to the placement of strain on and/or the release of strain from the piezoresistive component by sensing material **160**. Transducing platform **170** for one embodiment may comprise a structure of suitable elasticity to help support the piezoresistive component and to yield to placement of strain on the piezoresistive component, helping to enhance sensitivity of the piezoresistive component to change in volume of sensing material **160**. Transducing platform **170** for one embodiment may comprise a heater component to help control temperature of sensing material **160** to help control sensitivity of sensing material **160** to one or more target particles and/or to help control selectivity of sensing material **160** to one or more target particles in the presence of one or more non-target particles.

[**0044**] Transducing platform **170** for one embodiment may comprise a microelectromechanical system (MEMS) device or micromachine. Transducing platform **170** for one embodiment may comprise any suitable microhotplate structure. Transducing platform **170** for one embodiment may comprise any suitable microcantilever structure. Transducing platform **170** for one embodiment may comprise any suitable diaphragm structure. Transducing platform **170** may be formed in any suitable manner using any suitable techniques, including metal oxide semiconductor (MOS) processing techniques for example.

[**0045**] For block **204**, sensing material **160** is formed relative to transducing platform **170** to allow transducing platform **170** to sense change in volume of sensing material **160**. Sensing material **160** for one embodiment may be formed directly or indirectly over transducing platform **170**. Sensing material **160** for one embodiment may be formed directly or indirectly over a piezoresistive component of transducing platform **170**. Sensing material **160** may be formed in any suitable manner to comprise any suitable material that changes volume when exposed to any suitable one or more target particles. Sensing material **160** for one embodiment may be formed to comprise any suitable material that expands when exposed to any suitable one or more target particles. Such expansion of sensing material **160** may or may not be reversible. Sensing material **160** for one embodiment may be formed to comprise any suitable material that contracts when exposed to any suitable one or more target particles. Such contraction of sensing material **160** may or may not be reversible.

[**0046**] For block **206**, transducing platform **170** may be coupled to controller **110**.

[**0047**] Operations for blocks **202**, **204**, and **206** may be performed in any suitable order and may or may not be performed so as to overlap in time the performance of any suitable operation with any other suitable operation.

[**0048**] Controller **110** may use sensor **150** in any suitable manner to sense the presence of a target particle in an environment near sensor **150**. For one embodiment, controller **110** may use sensor **150** in accordance with a flow diagram **300** of **FIG. 3**.

[**0049**] For block **302** of **FIG. 3**, controller **110** uses transducing platform **170** to sense a relative volume of sensing material **160**. Controller **110** may use transducing platform **170** to sense a relative volume of sensing material **160** in any suitable manner.

[**0050**] Controller **110** for one embodiment may sense whether the volume of sensing material **160** changed relative to a prior volume sensing. Controller **110** for one embodiment may sense whether the volume of sensing material **160** increased or decreased relative to one or more prior volume sensings. Controller **110** for one embodiment may sense the extent to which the volume of sensing material **160** increased or decreased relative to one or more prior volume sensings and/or predetermined values.

[**0051**] For block **304**, controller **110** identifies whether a target particle is near sensing material **160** based on the sensed relative volume. Controller **110** may identify whether a target particle is near sensing material **160** in any suitable manner based on the sensed relative volume.

[**0052**] Controller **110** for one embodiment may identify a target particle is near sensing material **160** if the sensed volume changed from a prior volume sensing. Controller **110** for one embodiment may identify a target particle is near sensing material **160** if the sensed volume increased from one or more prior volume sensings. Controller **110** for one embodiment may identify a target particle is near sensing material **160** if the sensed volume increased by a predetermined amount from a prior volume sensing, such as an initial volume sensing for example, or from a predetermined value. Controller **110** for one embodiment may identify a target particle is near sensing material **160** if the sensed volume decreased from one or more prior volume sensings. Controller **110** for one embodiment may identify a target particle is near sensing material **160** if the sensed volume decreased by a predetermined amount from a prior volume sensing or from a predetermined value. Controller **110** for one embodiment may identify an amount or concentration of a target particle near sensing material **160** based on the extent to which the volume of sensing material **160** increased or decreased relative to one or more prior volume sensings and/or predetermined values.

[**0053**] If controller **110** identifies for block **304** that a target particle is near sensing material **160**, controller **110** for one embodiment for block **306** may output a signal indicating the presence of a target particle to output device **120**. Controller **110** for one embodiment may output a signal indicating the amount or concentration of a target particle sensed near sensing material **160**. If controller **110** identifies for block **304** that a target particle is not near sensing material **160**, controller **110** for one embodiment for block **308** may output a signal indicating the absence of a target particle to output device **120**.

[**0054**] Output device **120** may comprise any suitable circuitry and/or equipment to respond to a signal output from controller **110** in any suitable manner. Output device **120** for one embodiment may provide a suitable auditory output and/or a suitable visual output in response to a signal from controller **110**. Output device **120** for one embodiment may provide a suitable auditory output and/or a suitable visual output to indicate the amount or concentration of a target particle sensed near sensor **150**. Output device **120** for one embodiment may provide a suitable tactile output, such as vibration for example, in response to a signal from controller **110**. Output device **120** for one embodiment may actuate other circuitry and/or equipment in response to a signal from controller **110**, for example, to help control a process involving a target particle or to help clear a target particle from an environment near sensor **150**.

[**0055**] Controller **110** for one embodiment may repeat operations for blocks **302**, **304**, **306**, and/or **308** to continue to monitor the relative volume of sensing material **160**.

[**0056**] Sensing device **100** may perform operations for blocks **302-308** in any suitable order and may or may not overlap in time the performance of any suitable operation with any other suitable operation. Sensing device **100** for one embodiment may, for example, perform operations for blocks **302**, **304**, **306**, and/or **308** substantially continuously or discretely at a suitable rate.

[**0057**] Controller **110** for another embodiment may output a signal to output device **120** for block **306** and/or block **308** generally only when the sensed relative volume of sensing material **160** changes, or changes beyond a certain amount, from a prior sensing. Controller **110** for another embodiment may output a signal to output device **120** for block **306** generally only when the absence of a target particle was identified based on a just prior sensing and/or when an identified amount or concentration of a target particle near sensing material **160** changes, or changes beyond a certain amount, from a prior sensing. Controller **110** for another embodiment may output a signal to output device **120** for block **308** generally only when the presence of a target particle was identified based on a just prior sensing.

[**0058**] Piezoresistive Chemical Sensor

[**0059**] Sensor **150** for one embodiment may comprise a piezoresistive chemical sensor. **FIG. 4** illustrates a flow diagram **400** summarizing embodiments to form a piezoresistive chemical sensor for blocks **202** and **204** of **FIG. 2**.

[**0060**] One or more embodiments of flow diagram **400** are described with reference to blocks **402**, **404**, **406**, **416**, **418**,

420, and **422** of **FIG. 4** and with reference to **FIGS. 5**, **6**, and **7** to form a piezoresistive chemical sensor **600** having a sensing layer **550**, corresponding to sensing material **160** of **FIG. 1**, over a microhotplate structure **500**, corresponding to transducing platform **170** of **FIG. 1**. Sensing layer **550** comprises a chemical active material that changes volume when exposed to one or more target particles. Microhotplate structure **500** has a heater layer **530** to help control temperature of sensing layer **550** to help control sensitivity of sensing layer **550** to one or more target particles and/or to help control selectivity of sensing layer **550** to one or more target particles in the presence of one or more non-target particles. Heater layer **530** for one embodiment comprises a piezoelectric material to sense change in volume of sensing layer **550**.

[**0061**] For block **402** of **FIG. 4**, a layer **520** comprising a dielectric material is formed over a substrate **510**. Dielectric layer **520** for one embodiment may help electrically and thermally insulate heater layer **530** from substrate **510**.

[**0062**] Substrate **510** may comprise any suitable material. For one embodiment where sensor **600** is formed at least in part using one or more metal oxide semiconductor (MOS) processing techniques, substrate **510** may comprise a suitable semiconductor material, such as silicon (Si) for example.

[**0063**] Dielectric layer **520** may comprise any suitable material and may be formed in any suitable manner to any suitable thickness over substrate **510**. Dielectric layer **520** for one embodiment may comprise silicon dioxide (SiO_2), for example, and may be deposited using, for example, a suitable chemical vapor deposition (CVD) technique and chemistry to a thickness in the range of, for example, approximately 100 nanometers (nm) to approximately 20,000 nm. Dielectric layer **520** for another embodiment may comprise, for example, magnesium oxide (MgO), cerium oxide (CeO_2), silicon nitride (Si_3N_4), or aluminum oxide (Al_2O_3).

[**0064**] Dielectric layer **520** for one embodiment may be patterned in any suitable manner using any suitable technique. Dielectric layer **520** for one embodiment may be patterned using, for example, suitable photolithography and etch techniques.

[**0065**] Dielectric layer **520** for one embodiment may be patterned in any suitable manner to define a platform **525** over a hollowed portion **515**, such as a pit for example, to be defined in substrate **510**. Platform **525** may be used to help support layers of sensor **600** over hollowed portion **515** to help thermally isolate such layers from substrate **510** and to help provide a structure of suitable elasticity to yield to placement of strain on any such layer.

[**0066**] For one embodiment, as illustrated in **FIG. 5**, dielectric layer **520** may be patterned to define platform **525** with support legs **521**, **522**, **523**, and **524** extending from platform **525** to regions of substrate **510** outside hollowed portion **515** to help support platform **525** over hollowed portion **515**. Dielectric layer **520** for one embodiment may also be patterned to expose portions **511**, **512**, **513**, and **514** of substrate **510** between support legs **521**, **522**, **523**, and **524** to allow hollowed portion **515** to be later etched in substrate **510**. Although described as having four support legs **521**, **522**, **523**, and **524**, dielectric layer **520** for another embodiment may be patterned to define one, two, three, or more than four support legs.

[**0067**] For block **404** of **FIG. 4**, heater layer **530** comprising a suitable piezoresistive material is formed over dielectric layer **520**. A piezoresistive material undergoes a change in its electrical resistance under mechanical strain. Heater layer **530** for one embodiment may be used to help control temperature of one or more layers over heater layer **530** and to sense change in volume of one or more layers over heater layer **530**.

[**0068**] Heater layer **530** may comprise any suitable piezoresistive material and may be formed in any suitable manner to any suitable thickness over dielectric layer **520**. Heater layer **530** for one embodiment may comprise polycrystalline silicon (polysilicon or poly-Si), for example, and may be deposited using, for example, a suitable chemical vapor deposition (CVD) technique and chemistry or a suitable physical vapor deposition (PVD) technique. Poly-Si for one embodiment may be deposited to a thickness in the range of approximately 40 nanometers (nm) to approximately 4,000 nm, for example, to form heater layer **530**.

[**0069**] Heater layer **530** for another embodiment may comprise, for example, a single crystal silicon (Si) heavily doped with a suitable material, such as boron (B) or a suitable Group V element for example. Group V elements include phosphorous (P), and arsenic (As), for example.

[**0070**] Heater layer **530** for one embodiment may be patterned in any suitable manner using any suitable technique. Heater layer **530** for one embodiment may be patterned using, for example, suitable photolithography and etch techniques.

[**0071**] Heater layer **530** for one embodiment may be patterned in any suitable manner to help distribute heat in heating one or more layers over heater layer **530**. For one embodiment, as illustrated in **FIG. 5**, heater layer **530** may be patterned to define a serpentine ribbon portion **535** over platform **525**. Heater layer **530** for one embodiment may also be patterned to define a suitable number of electrical leads. For one embodiment, as illustrated in **FIG. 5**, heater layer **530** may be patterned to define leads **531** and **533** extending from serpentine ribbon portion **535** over support legs **521** and **523**, respectively.

[**0072**] Heater layer **530** may function as a resistive heater by inducing current flow across heater layer **530**. As heater layer **530** comprises piezoresistive material, heater layer **530** for one embodiment may also function as a strain gauge to measure strain on heater layer **530** by sensing electrical resistance of heater layer **530**. Because the expansion of one or more layers over heater layer **530** places a strain on heater layer **530** and because the contraction of one or more layers over heater layer **530** may release strain from heater layer **530**, heater layer **530** may be used to sense change in volume of one or more layers over heater layer **530**.

[**0073**] Heater layer **530** for one embodiment, as illustrated in **FIG. 5**, may be patterned to define only two leads **531** and **533** across which current may be induced to flow and across which electrical resistance may be sensed. Heater layer **530** for another embodiment may be patterned to define three, four, or more leads any suitable pair of which may be used to induce current flow through heater layer **530** and any suitable pair of which may be used to sense electrical resistance of heater layer **530**. For another embodiment, heater layer **530** may be conductively coupled to a suitable number of leads under heater layer **530** and/or over heater layer **530**.

[0074] Heater layer **530** for one embodiment may also be patterned to expose portions **511**, **512**, **513**, and **514** of substrate **510** to allow hollowed portion **515** to be later etched in substrate **510**.

[0075] For block **406** of **FIG. 4**, a layer **540** comprising a dielectric material is formed over heater layer **530**. Dielectric layer **540** for one embodiment may help electrically insulate heater layer **530** from one or more layers over heater layer **530**.

[0076] Dielectric layer **540** may comprise any suitable material and may be formed in any suitable manner to any suitable thickness over heater layer **530**. Dielectric layer **540** for one embodiment may comprise silicon dioxide (SiO_2), for example, and may be deposited using, for example, a suitable chemical vapor deposition (CVD) technique and chemistry to a thickness in the range of, for example, approximately 70 nanometers (nm) to approximately 7,000 nm. Dielectric layer **540** for another embodiment may comprise, for example, magnesium oxide (MgO), cerium oxide (CeO_2), silicon nitride (Si_3N_4), or aluminum oxide (Al_2O_3).

[0077] Dielectric layer **540** for one embodiment may be patterned in any suitable manner using any suitable technique. Dielectric layer **540** for one embodiment may be patterned using, for example, suitable photolithography and etch techniques.

[0078] Dielectric layer **540** for one embodiment may be patterned to expose portions **511**, **512**, **513**, and **514** of substrate **510** to allow hollowed portion **515** to be later etched in substrate **510**. Dielectric layer **540** for one embodiment, as illustrated in **FIG. 6**, may be similarly patterned as dielectric layer **520**.

[0079] For block **416** of **FIG. 4**, substrate **510** is etched to form hollowed portion **515**. For one embodiment, as illustrated in **FIGS. 6 and 7**, exposed portions **511**, **512**, **513**, and **514** of substrate **510** may be etched such that support legs **521**, **522**, **523**, and **524** support layers on platform **525** over hollowed portion **515**. Etching hollowed portion **515** for one embodiment may help thermally isolate such layers from substrate **510**.

[0080] Substrate **510** may be etched in any suitable manner using any suitable etch technique to form hollowed portion **515** of any suitable size and contour. Substrate **510** for one embodiment may be etched to form hollowed portion **515** using suitable photolithography and etch techniques. Substrate **510** for one embodiment may be etched using dielectric layer **540** as a mask. For another embodiment, substrate **510** may be etched from beneath substrate **510** using a suitable backside or bulk micromachining technique to form a hollowed portion of suitable size and contour through substrate **510**.

[0081] For block **418** of **FIG. 4**, sensing layer **550** comprising a chemical active material that changes volume when exposed to one or more target particles is formed over dielectric layer **540**. Sensing layer **550** for one embodiment helps sense a target particle in an environment near sensing layer **550** by expanding in the presence of a target particle and placing strain on heater layer **530**. Sensing layer **550** for one embodiment helps sense a target particle in an environment near sensing layer **550** by contracting in the presence of a target particle.

[0082] Sensing layer **550** for one embodiment may comprise any suitable chemical active material that expands when exposed to any suitable one or more target particles. Such expansion of sensing layer **550** may or may not be reversible.

[0083] Where sensing layer **550** is to sense hydrogen (H_2), for example, sensing layer **550** for one embodiment may comprise a suitable rare earth element. Rare earth elements include scandium (Sc), yttrium (Y), lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), lutetium (Lu), actinium (Ac), thorium (Th), protactinium (Pa), uranium (U), neptunium (Np), plutonium (Pu), americium (Am), curium (Cm), berkelium (Bk), californium (Cf), einsteinium (Es), fermium (Fm), mendelevium (Md), nobelium (No), and lawrencium (Lr).

[0084] Sensing layer **550** for one embodiment may comprise an alloy comprising more than one suitable rare earth element. Sensing layer **550** for one embodiment may comprise an alloy of one or more suitable rare earth elements with one or more other elements. Sensing layer **550** for one embodiment may comprise an alloy of one or more suitable rare earth elements with one or more other elements that include one or more suitable Group II elements. Group II elements include magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba), and radium (Ra). Sensing layer **550** for one embodiment may comprise an alloy of one or more suitable rare earth elements with one or more other elements that include aluminum (Al), copper (Cu), cobalt (Co), and/or iridium (Ir).

[0085] Sensing layer **550** for one embodiment may comprise one or more suitable rare earth elements doped with one or more other elements. Sensing layer **550** for one embodiment may comprise one or more suitable rare earth elements doped with one or more other elements that include one or more suitable Group II elements. Sensing layer **550** for one embodiment may comprise one or more suitable rare earth elements doped with one or more other elements that include aluminum (Al), copper (Cu), cobalt (Co), and/or iridium (Ir).

[0086] Sensing layer **550** for one embodiment may comprise a suitable material having approximately 15% atomic weight or more yttrium (Y).

[0087] Where sensing layer **550** comprises, for example, a material comprising a suitable rare earth element to sense hydrogen (H_2) and is exposed to hydrogen (H_2), the hydrogen (H_2) atoms are presumably incorporated into the lattice of the material for sensing layer **550**, causing the lattice to expand and therefore place strain on heater layer **530**. Further exposure to hydrogen (H_2) presumably causes the lattice to expand further.

[0088] As one example where sensing layer **550** comprises yttrium (Y), for example, the exposure of yttrium (Y) to hydrogen (H_2) leads to the following chemical reaction.

$$Y + H_2 \longrightarrow YH_2 \xleftrightarrow{1/2H_2} YH_3$$

[0089] Once the irreversible formation of yttrium dihydride (YH_2) occurs, further exposure to hydrogen (H_2) results in yttrium trihydride (YH_3) which occupies a larger volume relative to yttrium dihydride (YH_2). Because the transition from yttrium dihydride (YH_2) to yttrium trihydride (YH_3) is reversible, sensing layer **550** may be restored to its yttrium dihydride (YH_2) species for re-use in sensing hydrogen (H_2) in an environment near sensing layer **550**.

[0090] Other suitable elements may exhibit similar reactions with hydrogen (H_2). Sensing layer **550** for one embodiment may therefore comprise a dihydride species of one or more suitable elements.

[0091] Where sensing layer **550** is to sense hydrogen (H_2), for example, sensing layer **550** for one embodiment may comprise a suitable Group II element. Group II elements include magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba), and radium (Ra). Sensing layer **550** for one embodiment may comprise an alloy comprising more than one suitable Group II element. Sensing layer **550** for one embodiment may comprise an alloy of one or more suitable Group II elements with one or more other elements that include one or more suitable transition metals, such as manganese (Mn), iron (Fe), cobalt (Co), and/or nickel (Ni) for example. Sensing layer **550** for one embodiment may comprise a suitable magnesium-manganese (Mg_xMn_y) alloy, a suitable magnesium-iron (Mg_xFe_y) alloy, a suitable magnesium-cobalt (Mg_xCo_y) alloy, or a suitable magnesium-nickel (Mg_xNi_y) alloy. Sensing layer **550** for one embodiment may comprise one or more suitable Group II elements doped with one or more other elements.

[0092] Sensing layer **550** for one embodiment may comprise a suitable material having approximately 40% atomic weight or more magnesium (Mg).

[0093] Where sensing layer **550** is to sense hydrogen (H_2), for example, sensing layer **550** for one embodiment may comprise lithium (Li). Sensing layer **550** for one embodiment may comprise an alloy of lithium (Li) with one or more other elements. Sensing layer **550** for one embodiment may comprise a suitable Group VB element. Group VB elements include niobium (Nb) and tantalum (Ta), for example. Sensing layer **550** for one embodiment may comprise an alloy of a suitable Group VB element with one or more other elements. Sensing layer **550** for one embodiment may comprise palladium (Pd), titanium (Ti), or zirconium (Zr). Sensing layer **550** for one embodiment may comprise an alloy of palladium (Pd), titanium (Ti), or zirconium (Zr) with one or more other elements. Sensing layer **550** for one embodiment may comprise zirconium-nickel (Zr_xNi_y).

[0094] Sensing layer **550** for one embodiment may comprise a suitable material having approximately 11% atomic weight or more palladium (Pd). Sensing layer **550** for one embodiment may comprise a suitable material having approximately 18% atomic weight or more titanium (Ti). Sensing layer **550** for one embodiment may comprise a suitable material having approximately 16% atomic weight or more zirconium (Zr). Sensing layer **550** for one embodiment may comprise a suitable material having approximately 40% atomic weight or more zirconium-nickel (Zr_x-Ni_y).

[0095] Sensing layer **550** for one embodiment may comprise any suitable polymer or combination of polymers that changes volume when exposed to any suitable one or more target particles. Example polymers include poly(vinyl acetate)(PVA), poly(isobutylene)(PIB), poly(ethylene vinyl acetate)(PEVA), poly(4-vinylphenol), poly(styrene-co-allyl alcohol), poly(methylstyrene), poly(N-vinylpyrrolidone), poly(styrene), poly(sulfone), poly(methyl methacrylate), and poly(ethylene oxide).

[0096] Sensing layer **550** for one embodiment may comprise any suitable chemical active material that contracts when exposed to any suitable one or more target particles. Such contraction of sensing layer **550** may or may not be reversible.

[0097] Sensing layer **550** may be formed in any suitable manner to any suitable thickness over dielectric layer **540**. Sensing layer **550** for one embodiment may be deposited, for example, using a suitable chemical vapor deposition (CVD) technique and chemistry, physical vapor deposition (PVD) technique, sputtering technique, solution deposition technique, focused ion beam deposition technique, electrolytic plating technique, or electroless plating technique. Suitable CVD techniques may include, for example, a suitable metal-organic CVD (MOCVD) technique or a suitable plasma-enhanced CVD (PECVD) technique. Suitable PVD techniques may include, for example, a suitable electron beam PVD (EBPVD) technique. The deposition technique used may depend, for example, on the material or materials to be used for sensing layer **550**, the thickness of the material or materials to be used for sensing layer **550**, and/or the temperature other materials of sensor **600** are capable of withstanding.

[0098] Where sensing layer **550** is to sense hydrogen (H_2), for example, sensing layer **550** for one embodiment may be formed to comprise a suitable hydride species of one or more suitable materials by initially exposing sensing layer **550** to hydrogen (H_2). Sensing layer **550** for another embodiment may be formed to comprise a suitable hydride species of one or more suitable materials by depositing the hydride species of one or more suitable materials to form sensing layer **550**.

[0099] Sensing layer **550** for one embodiment may be formed to a thickness of less than or equal to approximately 1,000 microns. Where sensing layer **550** is to comprise yttrium (Y), for example, sensing layer **550** for one embodiment may be deposited to a thickness in the range of approximately 30 nanometers (nm) to approximately 3,000 nm, for example. The thickness of sensing layer **550** to be used may depend, for example, on the material used for sensing layer **550**, the target particle(s) to be sensed with sensing layer **550**, and/or the concentration of target particle(s) to be sensed with sensing layer **550**.

[0100] Sensing layer **550** for one embodiment may comprise more than one sensing sublayer. Each such sublayer may be formed of any suitable material in any suitable manner to any suitable thickness. One or more sensing sublayers of sensing layer **550** may comprise any suitable chemical active material that changes volume when exposed to any suitable one or more target particles.

[0101] Sensing layer **550** for one embodiment may be patterned in any suitable manner using any suitable technique. Sensing layer **550** for one embodiment may be patterned using, for example, suitable photolithography and etch techniques.

[0102] Sensing layer **550** for one embodiment may be patterned into any suitable shape of any suitable size over platform **525**. Sensing layer **550** for one embodiment may be patterned to help form a suitable shape having a surface area suitable for exposure to a target particle in an environment near sensing layer **550**.

[0103] Sensing layer **550** for one embodiment may have a suitable underlying adhesion and/or diffusion barrier layer comprising a suitable material. Where, for example, dielectric layer **540** comprises silicon dioxide (SiO_2) and sensing layer **550** is to comprise yttrium (Y), an underlying layer comprising aluminum (Al), for example, may be formed.

[0104] For block **420** of **FIG. 4**, a selective barrier layer **560** may optionally be formed over sensing layer **550**. Barrier layer **560** for one embodiment selectively allows a target particle to permeate through barrier layer **560**, that is to pass from an environment near barrier layer **560** to sensing layer **550**, while helping to prevent or impede one or more non-target particles from passing through barrier layer **560**.

[0105] Barrier layer **560** may comprise any suitable selective barrier material. Barrier layer **560** for one embodiment may comprise a suitable material that helps prevent or impede one or more non-target particles that may be harmful to sensing layer **550** from passing through barrier layer **560**. Barrier layer **560** for one embodiment may comprise a suitable material that helps prevent or impede one or more non-target particles from reacting with sensing layer **550**, for example, to help prevent the formation of oxides or nitrides in sensing layer **550**. Barrier layer **560** for one embodiment may comprise a suitable material that helps prevent or impede one or more non-target particles that may be falsely sensed with sensing layer **550** as a target particle from passing through barrier layer **560**.

[0106] Where sensing layer **550** is to sense hydrogen (H_2), for example, barrier layer **560** for one embodiment may comprise a suitable material to prevent or impede oxygen (O), nitrogen (N), nitrogen oxides (N_xO_y), carbon oxides (C_xO_y) such as carbon monoxide (CO) for example, hydrogen sulfide (H_2S), isopropyl alcohol (IPA), ammonia, and/or hydrocarbons, for example, from passing through barrier layer **560** to sensing layer **550**.

[0107] Barrier layer **560** for one embodiment may comprise a suitable material that also changes volume when exposed to one or more target particles to be sensed with sensing layer **550**. Barrier layer **560** for one embodiment may therefore be a sublayer of sensing layer **550**.

[0108] Where sensing layer **550** is to sense hydrogen (H_2), for example, barrier layer **560** for one embodiment may comprise a suitable noble metal. Noble metals include palladium (Pd), platinum (Pt), iridium (Ir), silver (Ag), and gold (Au).

[0109] Barrier layer **560** for one embodiment may comprise an alloy comprising more than one suitable noble metal. Barrier layer **560** for one embodiment may comprise an alloy of one or more suitable noble metals with one or more other elements. Barrier layer **560** for one embodiment may comprise an alloy of one or more suitable noble metals with one or more other elements that include magnesium (Mg), aluminum (Al), calcium (Ca), titanium (Ti), cobalt (Co), rhodium (Rh), silver (Ag), and/or iridium (Ir).

[0110] Barrier layer **560** for one embodiment may comprise one or more suitable noble metals doped with one or more other elements. Barrier layer **560** for one embodiment may comprise one or more suitable noble metals doped with one or more other elements that include magnesium (Mg), aluminum (Al), calcium (Ca), titanium (Ti), cobalt (Co), rhodium (Rh), silver (Ag), and/or iridium (Ir).

[0111] Where sensing layer **550** is to sense hydrogen (H_2), for example, barrier layer **560** for one embodiment may comprise a suitable polymeric film material, a suitable vitreous material, and/or a suitable ceramic material.

[0112] Barrier layer **560** may be formed in any suitable manner to any suitable thickness over sensing layer **550**. Barrier layer **560** for one embodiment may be deposited, for example, using a suitable spraying technique, chemical vapor deposition (CVD) technique and chemistry, physical vapor deposition (PVD) technique, sputtering technique, solution deposition technique, dipping technique, focused ion beam deposition technique, electrolytic plating technique, or electroless plating technique. Suitable CVD techniques may include, for example, a suitable metal-organic CVD (MOCVD) technique or a suitable plasma-enhanced CVD (PECVD) technique. Suitable PVD techniques may include, for example, a suitable electron beam PVD (EBPVD) technique. The deposition technique used may depend, for example, on the material or materials to be used for barrier layer **560**, the thickness of the material or materials to be used for barrier layer **560**, and/or the temperature other materials of sensor **600** are capable of withstanding.

[0113] Where barrier layer **560** is to comprise palladium (Pd), for example, barrier layer **560** for one embodiment may be deposited to a thickness in the range of approximately 1.5 nanometers (nm) to approximately 150 nm, for example.

[0114] The thickness of barrier layer **560** to be used may depend, for example, on the material used for barrier layer **560**, the target particle(s) to be sensed with sensing layer **550**, and/or the concentration of target particle(s) to be sensed with sensing layer **550**, noting a thicker barrier layer **560** may exhibit a relatively lower permeability of a target particle. A thinner barrier layer **560** may help in sensing lower concentrations of a target particle with sensing layer **550** while a thicker barrier layer **560** may help in sensing higher concentrations of a target particle with sensing layer **550**.

[0115] Barrier layer **560** for one embodiment may comprise more than one sublayer. Each such sublayer may be formed of any suitable material in any suitable manner to any suitable thickness. Barrier layer **560** for one embodiment may comprise, for example, alternating doped and undoped noble metal sublayers. Barrier layer **560** for one embodiment may comprise an overlying barrier sublayer to help prevent degradation of barrier layer **560** due to, for example, relatively high concentrations of particles and/or catalytic poisons. Where barrier layer **560** is to allow hydrogen (H_2), for example, to pass through barrier layer **560** to sensing layer **550**, the overlying barrier sublayer for one embodiment may comprise a polymer, such as a polyimide, an acrylic, nylon, a urethane, an epoxy, a fluorine containing resin, and/or polystyrene for example. The overlying barrier sublayer for another embodiment may comprise a non-polymer, such as silicon dioxide (SiO_2) or aluminum (Al) for example.

[0116] Barrier layer **560** for one embodiment may be patterned in any suitable manner using any suitable technique. Barrier layer **560** for one embodiment may be patterned using, for example, suitable photolithography and etch techniques.

[0117] Barrier layer **560** for one embodiment may be patterned into any suitable shape of any suitable size over platform **525**. Barrier layer **560** for one embodiment may be patterned to help cover exposed surface area of sensing layer **550**.

[0118] For block **422** of **FIG. 4**, sensor **600** for one embodiment may be packaged. Sensor **600** may be packaged in any suitable manner using any suitable packaging technique. Where heater layer **530** is patterned to define or is conductively coupled to only two leads, sensor **600** for one embodiment has only those two leads and may be packaged using only two wire bonds, for example. Forming sensor **600** with fewer leads may allow more sensors similar to sensor **600** to be formed on the same one substrate.

[0119] Operations for blocks **402, 404, 406, 416, 418, 420,** and/or **422** of **FIG. 4** may be performed in any suitable order and may or may not be performed so as to overlap in time the performance of any suitable operation with any other suitable operation. As one example, substrate **510** may be etched to form a hollowed portion for block **416** at any suitable time. As another example, sensor **600** may be packaged for block **422** prior to performing operations for block **418**. Also, any other suitable operation may be performed to help form a sensor in accordance with blocks **402, 404, 406, 416, 418, 420,** and/or **422** of **FIG. 4**. As one example, a suitable adhesion and/or barrier layer may be formed where desired.

[0120] The geometry of the support structure for platform **525**, the geometry of the layers over platform **525**, and the thickness, processing, and/or chemistry of materials used, for example, may influence the elastic properties of supported platform **525** and may therefore influence the strain sensitivity of heater layer **530**. Sensor **600** may therefore be designed and formed as desired to help increase or decrease the strain sensitivity of heater layer **530**.

[0121] Use of Piezoresistive Chemical Sensor

[0122] Sensor **600** may be used with any suitable circuitry and/or equipment in any suitable manner to sense the presence of a target particle in an environment near sensor **600**.

[0123] **FIG. 8** illustrates, for one embodiment, a sensing device **800** comprising sensor **600**, control circuitry **811**, a heater energization source **812**, and a heater resistance detector **813**. Control circuitry **811**, heater energization source **812**, and heater resistance detector **813** collectively correspond to controller **110** of sensing device **100** of **FIG. 1**.

[0124] Control circuitry **811** is coupled to heater energization source **812** and to heater resistance detector **813**. Control circuitry **811** for one embodiment may also be coupled to or in wireless communication with an output device **820**. Output device **820** may or may not be a component of sensing device **800**. Output device **820** corresponds to output device **120** for sensing device **100** of **FIG. 1**.

[0125] Heater energization source **812** and heater resistance detector **813** are each coupled to heater layer **530** of sensor **600**. Heater energization source **812** may be coupled to any suitable pair of leads for heater layer **530**, and heater resistance detector **813** may be coupled to any suitable pair of leads for heater layer **530**. Heater energization source **812** and heater resistance detector **813** for one embodiment, as illustrated in **FIG. 8**, may each be coupled to leads **531** and **533** defined by heater layer **530**.

[0126] Control circuitry **811** may control heater energization source **812** and heater resistance detector **813** to sense the presence of a target particle in an environment near sensor **600** in any suitable manner. Control circuitry **811** for one embodiment may control heater energization source **812** and heater resistance detector **813** to sense the presence of a target particle in an environment near sensor **600** in accordance with a flow diagram **900** of **FIG. 9**.

[0127] Control circuitry **811** for block **902** of **FIG. 9** controls heater energization source **812** to energize heater layer **530** of sensor **600**, and therefore heat sensing layer **550** of sensor **600**, and for block **904** controls heater energization source **812** to control the energization of heater layer **530** to help control temperature of sensing layer **550**. Control circuitry **811** for one embodiment may heat sensing layer **550** to help increase the rate of interaction of material of sensing layer **550** with a target particle and therefore enhance the sensitivity of sensing layer **550** to a target particle. Heating sensing layer **550** for one embodiment may therefore help in sensing relatively lower concentrations of a target particle with sensing layer **550** and/or help increase the response speed of sensing layer **550**. Heating sensing layer **550** for one embodiment may help enhance selectivity of sensing layer **550** to one or more target particles in the presence of one or more non-target particles.

[0128] Heater energization source **812** may comprise any suitable circuitry to energize heater layer **530** in any suitable manner. Heater energization source **812** for one embodiment may comprise a voltage source and energize heater layer **530** by applying a suitable voltage across heater layer **530** to induce current flow through heater layer **530**. Heater energization source **812** for another embodiment may comprise a current source to induce current flow through heater layer **530**.

[0129] Control circuitry **811** may comprise any suitable circuitry to control heater energization source **812** in any suitable manner to energize heater layer **530** and to control the energization of heater layer **530** in any suitable manner. Control circuitry **811** for one embodiment may control heater energization source **812** to pulse heater layer **530** at a predetermined rate, for example, to help consume less power. Control circuitry **811** for one embodiment may comprise a suitable data processing unit to control the energization of heater layer **530** in accordance with a suitable predetermined temperature program.

[0130] For block **906**, control circuitry **811** controls heater energization source **812** and/or heater resistance detector **813** to sense electrical resistance of heater layer **530** and therefore sense the relative volume of sensing layer **550**.

Heater resistance detector **813** may comprise any suitable circuitry to sense resistance of heater layer **530** in any suitable manner.

[**0131**] Where heater energization source **812** comprises a current source capable of generating a relatively constant current flow through heater layer **530**, heater resistance detector **813** for one embodiment may comprise a voltage detector to measure a voltage across heater layer **530**. Because resistance is equal to voltage divided by current, that is R=V/I, and because the amount of current flow through heater layer **530** may be held relatively constant, heater resistance detector **813** may effectively sense resistance of heater layer **530** by measuring voltage across heater layer **530**.

[**0132**] Where heater energization source **812** comprises a voltage source capable of generating a relatively constant voltage across heater layer **530**, heater resistance detector **813** for one embodiment may comprise a current detector and may effectively sense resistance of heater layer **530** by measuring current flow through heater layer **530**.

[**0133**] Control circuitry **811** for one embodiment may control heater energization source **812** and heater resistance detector **813** that together form a resistor bridge circuit to measure resistance of heater layer **530**.

[**0134**] Control circuitry **811** for one embodiment may control heater energization source **812** and heater resistance detector **813** to form an active feedback system that can change voltage across heater layer **530** and/or that can change current through heater layer **530** and monitor the current-voltage relationship of heater layer **530** to measure resistance of heater layer **530**.

[**0135**] For block **908**, control circuitry **811** identifies whether a target particle is near sensing layer **550** of sensor **600** based on the sensed resistance. Control circuitry **811** may identify whether a target particle is near sensing layer **550** in any suitable manner based on the sensed resistance.

[**0136**] Control circuitry **811** for one embodiment may compare the sensed resistance, for example a measured voltage, a measured current, or a measured resistance for heater layer **530**, to one or more prior sensed and/or predetermined values to identify whether a target particle is near sensing layer **550** and/or to identify an amount or concentration of a target particle near sensing layer **550**.

[**0137**] If control circuitry **811** identifies for block **908** that a target particle is near sensing layer **550**, control circuitry **811** for one embodiment for block **910** may output a signal indicating the presence of a target particle to output device **820**. Control circuitry **811** for one embodiment may output a signal indicating the amount or concentration of a target particle sensed near sensing layer **550**. If control circuitry **811** identifies for block **908** that a target particle is not near sensing layer **550**, control circuitry **811** for one embodiment for block **912** may output a signal indicating the absence of a target particle to output device **820**.

[**0138**] Control circuitry **811** for one embodiment may repeat operations for blocks **904**, **906**, **908**, **910**, and/or **912** to continue to help control temperature of sensing layer **550** and monitor resistance of heater layer **530**. Control circuitry **811** for one embodiment for block **904** may also control the energization of heater layer **530** to help refresh the sensing capability of sensing layer **550**. Where sensing layer **550** comprises a material that undergoes a reversible reaction with hydrogen (H_2), for example, by changing from a dihydride species to a trihydride species, for example, control circuitry **811** for one embodiment may control heater energization source **812** to control the energization of heater layer **530** to help return the material to its dihydride species. Control circuitry **811** for one embodiment may control heater energization source **812** to heat sensing layer **550** to one temperature for enhanced sensitivity and/or selectivity and to a higher temperature to refresh the sensing capability of sensing layer **550**.

[**0139**] Sensing device **800** may perform operations for blocks **902-912** in any suitable order and may or may not overlap in time the performance of any suitable operation with any other suitable operation. Sensing device **800** for one embodiment may, for example, perform operations for blocks **904**, **906**, **908**, **910**, and/or **912** substantially continuously or discretely at a suitable rate.

[**0140**] Control circuitry **811** for another embodiment may output a signal to output device **820** for block **910** and/or block **912** generally only when the sensed resistance of heater layer **530** changes, or changes beyond a certain amount, from a prior sensed resistance. Control circuitry **811** for another embodiment may output a signal to output device **820** for block **910** generally only when the absence of a target particle was identified based on a just prior sensed resistance and/or when an identified amount or concentration of a target particle near sensing layer **550** changes, or changes beyond a certain amount, from a prior sensed resistance. Control circuitry **811** for another embodiment may output a signal to output device **820** for block **912** generally only when the presence of a target particle was identified based on a just prior sensed resistance.

[**0141**] Optional Heat Distribution Layer

[**0142**] Referring to **FIG. 4**, one or more embodiments of flow diagram **400** are described with reference to blocks **402**, **404**, **406**, **408**, **410**, **416**, **418**, **420**, and **422** and with reference to **FIGS. 5, 10,** and **11** to form a piezoresistive chemical sensor **1100** having sensing layer **550** over a microhotplate structure **1000** having a heat distribution layer **570**. Heat distribution layer **570** helps distribute heat evenly from heater layer **530** to sensing layer **550**.

[**0143**] After dielectric layer **540** is formed over heater layer **530** for block **406** of **FIG. 4**, heat distribution layer **570** may be formed for block **408** over dielectric layer **540**.

[**0144**] Heat distribution layer **570** may comprise any suitable material and may be formed in any suitable manner to any suitable thickness over dielectric layer **540**. Heat distribution layer **570** for one embodiment may comprise a suitable conductive material, such as aluminum (Al) or copper (Cu) for example, and may be deposited using, for example, a suitable chemical vapor deposition (CVD) technique and chemistry, a suitable physical vapor deposition (PVD) technique, or a suitable electrolytic plating technique to a thickness in the range of, for example, approximately 30 nanometers (nm) to approximately 6,000 nm.

[**0145**] Heat distribution layer **570** may be patterned in any suitable manner using any suitable technique. Heat distribution layer **570** for one embodiment may be patterned using, for example, suitable photolithography and etch techniques. Heat distribution layer **570** for one embodiment may be formed using a suitable dual damascene technique and therefore patterned as heat distribution layer **570** is formed.

[**0146**] Heat distribution layer **570** for one embodiment may be patterned in any suitable manner to help distribute heat evenly to one or more layers over heat distribution layer **570**. For one embodiment, as illustrated in **FIG. 10**, heat distribution layer **570** may be patterned to define a substantially uniform portion **575** of a suitable shape over platform **525**.

[**0147**] Heat distribution layer **570** for one embodiment may also be patterned to define a suitable number of electrical leads. In this manner, heat distribution layer **570** for one embodiment may be used to help monitor temperature near sensing layer **550** by inducing current flow through heat distribution layer **570** and sensing electrical resistance of heat distribution layer **570** to identify a temperature near sensing layer **550**. The identified temperature may be used, for example, to help control the energization of heater layer **530**. Sensing device **800** of **FIG. 8**, for example, may be modified to sense a target particle with sensor **1100** by using an energization source and resistance detector under control of control circuitry **811** to identify a temperature near sensing layer **550** using heat distribution layer **570**.

[**0148**] Heat distribution layer **570** for one embodiment, as illustrated in **FIG. 10**, may be patterned to define leads **571**, **572**, **573**, and **574** extending from portion **575** over support legs **521**, **522**, **523**, and **524**, respectively. Any suitable pair of leads **571**, **572**, **573**, and **574** may be used to induce current flow through heat distribution layer **570**. Any suitable pair of leads **571**, **572**, **573**, and **574** may be used to sense electrical resistance of heat distribution layer **570**. Heat distribution layer **570** for another embodiment may be patterned to define only two, three, or more leads. For another embodiment, heat distribution layer **570** may be conductively coupled to a suitable number of leads under heat distribution layer **570** and/or over heat distribution layer **570**. For one embodiment, heat distribution layer **570** may have one or more leads conductively coupled to one or more leads for one or more other layers, such as heater layer **530** for example, to help define one or more common leads, such as a ground lead for example, for multiple layers and therefore to help reduce the number of leads for sensor **1100**. Heat distribution layer **570** for one embodiment may also be patterned to expose portions **511**, **512**, **513**, and **514** of substrate **510** to allow hollowed portion **515** to be later etched in substrate **510**.

[**0149**] For block **410** of **FIG. 4**, a layer **577** comprising a dielectric material may be formed over heat distribution layer **570**. Dielectric layer **577** for one embodiment may help electrically insulate heat distribution layer **570** from one or more layers over heat distribution layer **570**. The description pertaining to the formation and patterning of dielectric layer **540** for block **406** similarly applies to the formation and patterning of dielectric layer **577** for block **410**.

[**0150**] The geometry of heat distribution layer **570** and dielectric layer **577** and the thickness, processing, and/or chemistry of materials used, for example, may influence the elastic properties of supported platform **525** and may therefore influence the strain sensitivity of heater layer **530**. Sensor **1100** may therefore be designed and formed as desired to help increase or decrease the strain sensitivity of heater layer **530**.

[**0151**] Operations for blocks **402**, **404**, **406**, **408**, **410**, **416**, **418**, **420**, and/or **422** of **FIG. 4** may be performed in any suitable order and may or may not be performed so as to overlap in time the performance of any suitable operation with any other suitable operation. As one example, substrate **510** may be etched to form a hollowed portion for block **416** at any suitable time. As another example, sensor **600** may be packaged for block **422** prior to performing operations for block **418**. Also, any other suitable operation may be performed to help form a sensor in accordance with blocks **402**, **404**, **406**, **408**, **410**, **416**, **418**, **420**, and/or **422** of **FIG. 4**. As one example, a suitable adhesion and/or barrier layer may be formed where desired.

[**0152**] Optional Contact Layer

[**0153**] Referring to **FIG. 4**, one or more embodiments of flow diagram **400** are described with reference to blocks **402**, **404**, **406**, **408**, **410**, **412**, **414**, **416**, **418**, **420**, and **422** and with reference to **FIGS. 5**, **12**, and **13** to form a piezoresistive chemical sensor **1300** having sensing layer **550** over a microhotplate structure **1200** having a contact layer defining contacts **581**, **582**, **583**, and **584** to be conductively coupled to sensing layer **550**. The contact layer for one embodiment may be used to help energize sensing layer **550** to help control sensitivity of sensing layer **550** to one or more target particles and/or to help control selectivity of sensing layer **550** to one or more target particles in the presence of one or more non-target particles. Where sensing layer **550** is to comprise a material that undergoes a change in its electrical properties in reacting with one or more target particles, the contact layer for one embodiment may be used to help sense electrical resistance of sensing layer **550** to help identify whether a target particle is near sensing layer **550**.

[**0154**] After dielectric layer **577** is formed over heat distribution layer **570** for block **410** of **FIG. 4**, the contact layer may be formed for block **412** over dielectric layer **577**.

[**0155**] The contact layer may comprise any suitable material and may be formed in any suitable manner to any suitable thickness over dielectric layer **577**. The contact layer for one embodiment may comprise a suitable conductive material, such as aluminum (Al), copper (Cu), platinum (Pt), or tungsten (W) for example, and may be deposited using, for example, a suitable chemical vapor deposition (CVD) technique and chemistry, a suitable physical vapor deposition (PVD) technique, or a suitable electrolytic plating technique to a thickness in the range of, for example, approximately 30 nanometers (nm) to approximately 6,000 nm.

[**0156**] The contact layer may be patterned in any suitable manner using any suitable technique to define contacts **581**, **582**, **583**, and **584**. The contact layer for one embodiment may be patterned using, for example, suitable photolithography and etch techniques. The contact layer for one embodiment may be formed using a suitable dual damascene technique and therefore patterned as the contact layer is formed.

[**0157**] For one embodiment, as illustrated in **FIG. 12**, the contact layer may be patterned to define for each contact

581, **582**, **583**, and **584** a pad over at least a portion of platform **525** and an electrical lead extending from the pad over support leg **521**, **522**, **523**, and **524**, respectively. Where sensing layer **550** is to comprise a material that undergoes a change in its electrical properties in reacting with one or more target particles, sensing layer **550** for one embodiment may be formed over the pads for conductive coupling to contacts **581**, **582**, **583**, and **584**. Any suitable pair of contacts **581**, **582**, **583**, and **584** may then be used to induce current flow through sensing layer **550**. Any suitable pair of contacts **581**, **582**, **583**, and **584** may be used to sense electrical resistance of sensing layer **550** to help identify whether a target particle is near sensing layer **550**.

[**0158**] As one example, sensing layer **550** may comprise yttrium dihydride (YH_2). Upon exposure to hydrogen (H_2), yttrium dihydride (YH_2) will react to form yttrium trihydride (YH_3) which has a greater electrical resistance. Whether hydrogen (H_2) is near sensing layer **550** may then be identified by sensing resistance of sensing layer **550**. Other suitable elements may exhibit similar reactions with hydrogen (H_2).

[**0159**] Although described as having four contacts **581**, **582**, **583**, and **584**, the contact layer for another embodiment may be patterned to define only two, three, or more contacts. For one embodiment, the contact layer may be patterned to define one or more contacts for conductive coupling to one or more leads for one or more other layers, such as heater layer **530** and/or heat distribution layer **570** for example, to help define one or more common leads, such as a ground lead for example, for multiple layers and therefore to help reduce the number of leads for sensor **1300**.

[**0160**] For block **414** of **FIG. 4**, a layer **590** comprising a dielectric material may be formed over contacts **581**, **582**, **583**, and **584** and patterned to expose at least a portion of the pads of contacts **581**, **582**, **583**, and **584**. The description pertaining to the formation and patterning of dielectric layer **540** for block **406** similarly applies to the formation and patterning of dielectric layer **590** for block **414**. Dielectric layer **590** for one embodiment may be planarized using a suitable chemical-mechanical polishing (CMP) technique, for example. Dielectric layer **590** for one embodiment may be formed as part of a suitable dual damascene technique to form the contact layer.

[**0161**] For block **418** of **FIG. 4**, sensing layer **550** may be formed over exposed portions of contacts **581**, **582**, **583**, and **584**. Sensing layer **550** for one embodiment may have a suitable underlying adhesion and/or diffusion barrier layer comprising a suitable material. Where, for example, contacts **581**, **582**, **583**, and **584** comprise aluminum (Al), dielectric layer **590** comprises silicon dioxide (SiO_2), and sensing layer **550** is to comprise yttrium (Y), an underlying layer comprising aluminum (Al), for example, may be formed.

[**0162**] The geometry of contacts **581**, **582**, **583**, and **584** and dielectric layer **590** and the thickness, processing, and/or chemistry of materials used, for example, may influence the elastic properties of supported platform **525** and may therefore influence the strain sensitivity of heater layer **530**. Sensor **1300** may therefore be designed and formed as desired to help increase or decrease the strain sensitivity of heater layer **530**.

[**0163**] Operations for blocks **402**, **404**, **406**, **408**, **410**, **412**, **414**, **416**, **418**, **420**, and/or **422** of **FIG. 4** may be performed in any suitable order and may or may not be performed so as to overlap in time the performance of any suitable operation with any other suitable operation. As one example, substrate **510** may be etched to form a hollowed portion for block **416** at any suitable time. As another example, sensor **600** may be packaged for block **422** prior to performing operations for block **418**. Also, any other suitable operation may be performed to help form a sensor in accordance with blocks **402**, **404**, **406**, **408**, **410**, **412**, **414**, **416**, **418**, **420**, and/or **422** of **FIG. 4**. As one example, a suitable adhesion and/or barrier layer may be formed where desired.

[**0164**] Although described as having the contact layer formed prior to forming sensing layer **550**, sensor **1300** for another embodiment may have sensing layer **550** formed over dielectric layer **577** and the contact layer formed over sensing layer **550**. Dielectric layer **590** for this embodiment may be formed over the contact layer and patterned to expose sensing layer **550** or may not be formed at all.

[**0165**] Although described as comprising heat distribution layer **570** and dielectric layer **577**, sensor **1300** for another embodiment may not comprise heat distribution layer **570** or dielectric layer **577**.

[**0166**] Use of Piezoresistive Chemical Sensor with Contact Layer

[**0167**] Sensor **1300** may be used with any suitable circuitry and/or equipment in any suitable manner to sense the presence of a target particle in an environment near sensor **1300**.

[**0168**] **FIG. 14** illustrates, for one embodiment, a sensing device **1400** comprising sensor **1300**, control circuitry **1411**, a heater energization source **1412**, a heater resistance detector **1413**, a sensing layer energization source **1414**, and a sensing layer resistance detector **1415**. Control circuitry **1411**, heater energization source **1412**, heater resistance detector **1413**, sensing layer energization source **1414**, and sensing layer resistance detector **1415** collectively correspond to controller **110** of sensing device **100** of **FIG. 1**.

[**0169**] Control circuitry **1411** is coupled to heater energization source **1412**, to heater resistance detector **1413**, to sensing layer energization source **1414**, and to sensing layer resistance detector **1415**. Control circuitry **1411** for one embodiment may also be coupled to or in wireless communication with an output device **1420**. Output device **1420** may or may not be a component of sensing device **1400**. Output device **1420** corresponds to output device **120** for sensing device **100** of **FIG. 1**.

[**0170**] Control circuitry **1411**, heater energization source **1412**, and heater resistance detector **1413** generally correspond to control circuitry **811**, heater energization source **812**, and heater resistance detector **813**, respectively, of sensing device **800** of **FIG. 8**. The description of sensing device **800** of **FIG. 8** may therefore similarly apply to sensing device **1400** of **FIG. 14** where applicable.

[**0171**] Sensing layer energization source **1414** and sensing layer resistance detector **1415** are each coupled to sensing layer **550** of sensor **1300**. Sensing layer energization source **1414** may be coupled to any suitable pair of contacts of sensor **1300**, and sensing layer resistance detector **1415** may be coupled to any suitable pair of contacts of sensor **1300**. Sensing layer energization source **1414** and sensing layer resistance detector **1415** for one embodiment, as illustrated in **FIG. 14**, may each be coupled to contacts **582** and **584**.

[**0172**] Control circuitry **1411** may control heater energization source **1412**, heater resistance detector **1413**, sensing layer energization source **1414**, and sensing layer resistance detector **1415** to sense the presence of a target particle in an environment near sensor **1300** in any suitable manner. Control circuitry **1411** for one embodiment may control heater energization source **1412**, heater resistance detector **1413**, sensing layer energization source **1414**, and sensing layer resistance detector **1415** to sense the presence of a target particle in an environment near sensor **1300** in accordance with a flow diagram **1500** of **FIG. 15**.

[**0173**] Blocks **1502**, **1504**, **1508**, **1510**, **1512**, and **1514** of flow diagram **1500** of **FIG. 15** generally correspond to blocks **902**, **904**, **906**, **908**, **910**, and **912**, respectively, of flow diagram **900** of **FIG. 9**. The description of flow diagram **900** of **FIG. 9** may therefore similarly apply to flow diagram **1500** of **FIG. 15** where applicable.

[**0174**] For block **1502** of **FIG. 15**, control circuitry **1411** controls heater energization source **1412** to energize heater layer **530** of sensor **1300** and therefore heat sensing layer **550** of sensor **1300**. Control circuitry **1411** for block **1504** controls heater energization source **1412** to control the energization of heater layer **530** to help control temperature of sensing layer **550**.

[**0175**] For block **1506**, control circuitry **1411** controls sensing layer energization source **1414** to energize sensing layer **550** of sensor **1300** and controls sensing layer resistance detector **1415** to sense electrical resistance of sensing layer **550**. Sensing layer energization source **1414** may comprise any suitable circuitry to energize sensing layer **550** in any suitable manner, and sensing layer resistance detector **1415** may comprise any suitable circuitry to sense resistance of sensing layer **550** in any suitable manner. The description of heater energization source **812** and heater resistance detector **813** of **FIG. 8** may similarly apply to sensing layer energization source **1414** and sensing layer resistance detector **1415** of **FIG. 14** where applicable.

[**0176**] For block **1508**, control circuitry **1411** controls heater energization source **1412** and/or heater resistance detector **1413** to sense electrical resistance of heater layer **530**.

[**0177**] For block **1510**, control circuitry **1411** identifies whether a target particle is near sensing layer **550** of sensor **1300** based on the sensed resistance of sensing layer **550** and/or based on the sensed resistance of heater layer **530**. Control circuitry **1411** may identify whether a target particle is near sensing layer **550** in any suitable manner based on the sensed resistance of either or both sensing layer **550** and heater layer **530**.

[**0178**] Control circuitry **1411** for one embodiment may compare the sensed resistance, for example a measured voltage, a measured current, or a measured resistance, of sensing layer **550** to one or more prior sensed and/or predetermined values and the sensed resistance of heater layer **530** to one or more prior sensed and/or predetermined values to identify whether a target particle is near sensing layer **550** and/or to identify an amount or concentration of a target particle near sensing layer **550**.

[**0179**] Control circuitry **1411** for one embodiment may identify that a target particle is near sensing layer **550** if either one or both comparisons identify that a target particle is near sensing layer **550**. Control circuitry **1411** for one embodiment may identify an amount or concentration of a target particle near sensing layer **550** based on either or both of the sensed resistances of sensing layer **550** and heater layer **530**. Control circuitry **1411** for one embodiment may use the sensed resistance of sensing layer **550** to identify an amount or concentration of a target particle near sensing layer **550** for relatively low sensed amounts or concentrations of a target particle and may use the sensed resistance of heater layer **530** to identify an amount or concentration of a target particle near sensing layer **550** for relatively high sensed amounts or concentrations of a target particle.

[**0180**] If control circuitry **1411** identifies for block **1510** that a target particle is near sensing layer **550**, control circuitry **1411** for one embodiment for block **1512** may output a signal indicating the presence of a target particle to output device **1420**. Control circuitry **1411** for one embodiment may output a signal indicating the amount or concentration of a target particle sensed near sensing layer **550**. If control circuitry **1411** identifies for block **1510** that a target particle is not near sensing layer **550**, control circuitry **1411** for one embodiment for block **1514** may output a signal indicating the absence of a target particle to output device **1420**.

[**0181**] Control circuitry **1411** for one embodiment may repeat operations for blocks **1504**, **1506**, **1508**, **1510**, **1512** and/or **1514** to continue to help control temperature of sensing layer **550** and monitor resistances of sensing layer **550** and heater layer **530**. Control circuitry **1411** for one embodiment for block **1504** may also control the energization of heater layer **530** to help refresh the sensing capability of sensing layer **550**.

[**0182**] Although illustrated as physically separate components, heater energization source **1412** and sensing layer energization source **1414** for one embodiment may comprise common circuitry to energize heater layer **530** and sensing layer **550**, respectively, under control of control circuitry **1411**. Heater resistance detector **1413** and sensing layer resistance detector **1415** for one embodiment may comprise common circuitry to sense resistance of heater layer **530** and sensing layer **550**, respectively, under control of control circuitry **1411**.

[**0183**] Sensing device **1400** may perform operations for blocks **1502-1514** in any suitable order and may or may not overlap in time the performance of any suitable operation with any other suitable operation. Sensing device **1400** for one embodiment may, for example, perform operations for block **1506** while and/or after performing operations for block **1508**. Sensing device **1400** for one embodiment may, for example, perform operations for blocks **1504**, **1506**, **1508**, **1510**, **1512**, and/or **1514** substantially continuously or discretely at a suitable rate.

[**0184**] Control circuitry **1411** for another embodiment may control sensing layer energization source **1414** to energize sensing layer **550** and to control energization of sensing layer **550** to help control sensitivity of sensing layer **550** to one or more target particles and/or to help control selectivity of sensing layer **550** to one or more target particles in the presence of one or more non-target particles.

Sensing device **1400** for this embodiment may or may not comprise and/or may or may not use sensing layer resistance detector **1415**.

[**0185**] Control circuitry **1411** for another embodiment may output a signal to output device **1420** for block **1512** and/or block **1514** generally only when the sensed resistance of heater layer **530** changes, or changes beyond a certain amount, from a prior sensed resistance and/or when the sensed resistance of sensing layer **550** changes, or changes beyond a certain amount, from a prior sensed resistance. Control circuitry **1411** for another embodiment may output a signal to output device **1420** for block **1512** generally only when the absence of a target particle was identified based on just prior sensed resistances and/or when an identified amount or concentration of a target particle near sensing layer **550** changes, or changes beyond a certain amount, from prior sensed resistances. Control circuitry **1411** for another embodiment may output a signal to output device **1420** for block **1514** generally only when the presence of a target particle was identified based on just prior sensed resistances.

[**0186**] Microcantilever Structure for Transducing Platform

[**0187**] Although described in connection with microhotplate structure **500** of **FIG. 5**, embodiments of flow diagram **400** of **FIG. 4** may also be used to form a piezoresistive chemical sensor having a suitable microcantilever structure for transducing platform **170** of **FIG. 1**.

[**0188**] **FIG. 16** illustrates, for one embodiment, a microcantilever structure **1600** that may be formed in accordance with embodiments of flow diagram **400** of **FIG. 4**. A cross-section of a piezoresistive chemical sensor formed in accordance with blocks **402**, **404**, **406**, **416**, **418**, **420**, and **422** of **FIG. 4** to have microcantilever structure **1600** for one embodiment may appear similarly as the cross-section of sensor **600** of **FIG. 6**. Microcantilever structure **1600** is formed by defining platform **525** to be bendable or deflectable along a suitable bend axis in response to placement of strain on one or more layers over platform **525**. Because the electrical resistance of the piezoresistive material of heater layer **530** over platform **525** changes as platform **525** is deflected to bend toward hollowed portion **515** or rebounds away from hollowed portion **515**, change in volume of sensing layer **550** may be sensed by sensing electrical resistance of heater layer **530** on platform **525**.

[**0189**] Microcantilever structure **1600** for one embodiment may be formed by patterning dielectric layer **520** for block **402** of **FIG. 4** to define one or more support legs to support platform **525** over hollowed portion **515** in substrate **510** while allowing platform **525** to be bent or deflected along a suitable bend axis in response to change in volume of one or more layers over platform **525**. Dielectric layer **520** may be patterned in any suitable manner. Dielectric layer **520** for one embodiment, as illustrated in **FIG. 16**, may be patterned to define support legs **523** and **524** extending outward from adjacent corners of platform **525**. Dielectric layer **520** for another embodiment may be patterned to define one or more support legs extending outward from the same one side of platform **525**.

[**0190**] Heater layer **530** for one embodiment may then be formed and patterned for block **404** of **FIG. 4** in any suitable manner to define a portion of a suitable shape, such as serpentine ribbon portion **535** for example, over platform **525** and/or to define two or more electrical leads for heater layer **530**. For one embodiment, as illustrated in **FIG. 16**, heater layer **530** may be patterned to define leads **533** and **534** extending from serpentine ribbon portion **535** over support legs **523** and **524**, respectively.

[**0191**] The geometry of the support structure for platform **525**, the geometry of the layers over platform **525**, and the thickness, processing, and/or chemistry of materials used, for example, may influence the elastic properties of supported platform **525** and may therefore influence the strain sensitivity of heater layer **530**. A sensor having microcantilever structure **1600** may therefore be designed and formed as desired to help increase or decrease the strain sensitivity of heater layer **530**.

[**0192**] Diaphragm Structure for Transducing Platform

[**0193**] Embodiments of flow diagram **400** of **FIG. 4** may also be used to form a piezoresistive chemical sensor having a suitable diaphragm structure for transducing platform **170** of **FIG. 1**.

[**0194**] **FIG. 17** illustrates, for one embodiment, a diaphragm structure **1700** that may be formed in accordance with embodiments of flow diagram **400** of **FIG. 4**. **FIG. 18** illustrates, for one embodiment, a piezoresistive chemical sensor **1800** formed in accordance with blocks **402**, **404**, **406**, **416**, **418**, **420**, and **422** of **FIG. 4** to have diaphragm structure **1700**. Diaphragm structure **1700** is formed by defining a membrane layer to span a hollowed portion of substrate **510** to help thermally isolate layers over the membrane layer from substrate **510** and to provide a structure of suitable elasticity to yield to placement of strain on any such layer.

[**0195**] Diaphragm structure **1700** for one embodiment, as illustrated in **FIGS. 17 and 18**, may be formed by forming dielectric layer **520** over substrate **510** for block **402** of **FIG. 4** and etching substrate **510** from its backside for block **416** to form hollowed portion **515** in substrate **510** with dielectric layer **520** spanning hollowed portion **515** to serve as a membrane layer.

[**0196**] Dielectric layer **520** may comprise any suitable material and may be formed to any suitable thickness to define a membrane layer of any suitable thickness over hollowed portion **515**. Dielectric layer **520** for one embodiment may comprise silicon dioxide (SiO_2), silicon nitride (Si_3N_4), or a suitable polymer, for example, and may be formed to a suitable thickness over substrate **510** to define a membrane layer having a thickness in the range of, for example, approximately 0.4 microns (μm) to approximately 2,000 μm.

[**0197**] Substrate **510** may be etched in any suitable manner using any suitable etch technique to form hollowed portion **515** of any suitable size and contour. Substrate **510** for one embodiment may be etched using a suitable selective etch chemistry that allows dielectric layer **520** to help serve as an etch stop. Substrate **510** for one embodiment may be etched using a suitable backside or bulk micromachining technique to form hollowed portion **515**.

[**0198**] Heater layer **530** for one embodiment may be formed over dielectric layer **520** and patterned for block **404** of **FIG. 4** in any suitable manner to define a portion of a suitable shape, such as serpentine ribbon portion **535** for example, over dielectric layer **520** and/or to define two or more electrical leads for heater layer **530**. For one embodiment, as illustrated in **FIG. 17**, heater layer **530** may be patterned to define leads **531** and **533** extending from serpentine ribbon portion **535**.

[**0199**] For another embodiment, substrate **510** may be etched to define a membrane layer from substrate **510** itself over a hollowed portion in substrate **510**. Substrate **510** may comprise any suitable material, such as silicon (Si) for example, and may be processed in any suitable manner to define a membrane layer of any suitable thickness over a hollowed portion of any suitable size and contour in substrate **510**. Substrate **510** for one embodiment may be subjected to a suitable backside or bulk micromachining technique to remove material from substrate **510** until a membrane layer of a suitable thickness is defined to span the resulting hollowed portion.

[**0200**] The geometry of the membrane layer and the hollowed portion spanned by the membrane layer, the geometry of the layers over the membrane layer, and the thickness, processing, and/or chemistry of materials used, for example, may influence the elastic properties of the membrane layer and may therefore influence the strain sensitivity of heater layer **530**. A sensor having diaphragm structure **1700** may therefore be designed and formed as desired to help increase or decrease the strain sensitivity of heater layer **530**.

[**0201**] Sensor with Piezoresistive Layer Separate from Heater Layer

[**0202**] **FIG. 19** illustrates a flow diagram **1900** summarizing embodiments to form for blocks **202** and **204** of **FIG. 2 a** piezoresistive chemical sensor having a piezoresistive layer separate from a heater layer. Blocks **1902, 1904, 1906, 1912, 1914, 1916, 1918, 1920, 1922, 1924,** and **1926** of flow diagram **1900** of **FIG. 19** generally correspond to blocks **402, 404, 406, 408, 410, 412, 414, 416, 418, 420,** and **422**, respectively, of flow diagram **400** of **FIG. 4**. The description of such blocks of flow diagram **400** of **FIG. 4** may therefore similarly apply to corresponding blocks of flow diagram **1900** of **FIG. 19** where applicable.

[**0203**] **FIG. 20** illustrates, for one embodiment, a microhotplate structure **2000** that may be formed in accordance with embodiments of flow diagram **1900** of **FIG. 19** to have a piezoresistive layer **545** separate from heater layer **530**. **FIG. 21** illustrates, for one embodiment, a piezoresistive chemical sensor **2100** formed in accordance with blocks **1902, 1904, 1906, 1908, 1910, 1920, 1922, 1924,** and **1926** of flow diagram **1900** of **FIG. 19** to have microhotplate structure **2000**.

[**0204**] For block **1904** of **FIG. 19**, heater layer **530** may comprise any suitable material to heat one or more layers over heater layer **530**. Heater layer **530** may or may not comprise a piezoresistive material for microhotplate structure **2000**. Heater layer **530** may comprise, for example, polycrystalline silicon (polysilicon or poly-Si) or a doped silicon (Si). Heater layer **530** may be formed in any suitable manner to any suitable thickness over dielectric layer **520** and may be patterned in any suitable manner using any suitable technique.

[**0205**] After dielectric layer **540** is formed over heater layer **530** for block **1906** of **FIG. 19**, piezoresistive layer **545** may be formed for block **1908** over dielectric layer **540**.

[**0206**] Piezoresistive layer **545** may comprise any suitable material and may be formed in any suitable manner to any suitable thickness over dielectric layer **540**. Piezoresistive layer **545** for one embodiment may comprise polycrystalline silicon (polysilicon or poly-Si), for example, and may be deposited using, for example, a suitable chemical vapor deposition (CVD) technique and chemistry or a suitable physical vapor deposition (PVD) technique to a thickness in the range of, for example, approximately 40 nanometers (nm) to approximately 4,000 nm.

[**0207**] Piezoresistive layer **545** for another embodiment may comprise, for example, a single crystal silicon (Si) heavily doped with a suitable material, such as boron (B) or a suitable Group V element for example. Group V elements include phosphorous (P), and arsenic (As), for example. For one embodiment where microhotplate structure **2000** may be formed using one or more non-MOS processing techniques, piezoresistive layer **545** may comprise, for example, lead zirconium titanate ($(Pb,Zr)TiO_3$), chromium nitride (CrN), or barium titanate ($BaTiO_3$).

[**0208**] Piezoresistive layer **545** may be patterned in any suitable manner using any suitable technique. Piezoresistive layer **545** for one embodiment may be patterned using, for example, suitable photolithography and etch techniques. For one embodiment, as illustrated in **FIG. 20**, piezoresistive layer **545** may be patterned to define a substantially uniform portion **546** of a suitable shape over platform **525**.

[**0209**] Piezoresistive layer **545** for one embodiment may also be patterned to define a suitable number of electrical leads. Piezoresistive layer **545** for one embodiment, as illustrated in **FIG. 20**, may be patterned to define leads **541, 542, 543,** and **544** extending from portion **546** over support legs **521, 522, 523,** and **524**, respectively. Any suitable pair of leads **541, 542, 543,** and **544** may be used to induce current flow through piezoresistive layer **545**. Any suitable pair of leads **541, 542, 543,** and **544** may be used to sense electrical resistance of piezoresistive layer **545**. Piezoresistive layer **545** for another embodiment may be patterned to define only two, three, or more leads. For another embodiment, piezoresistive layer **545** may be conductively coupled to a suitable number of leads under piezoresistive layer **545** and/or over piezoresistive layer **545**. For one embodiment, piezoresistive layer **545** may have one or more leads conductively coupled to one or more leads for one or more other layers, such as heater layer **530** for example, to help define one or more common leads, such as a ground lead for example, for multiple layers and therefore to help reduce the number of leads for sensor **2100**.

[**0210**] Piezoresistive layer **545** for one embodiment may also be patterned to expose portions **511, 512, 513,** and **514** of substrate **510** to allow hollowed portion **515** to be later etched in substrate **510**.

[**0211**] For block **1910** of **FIG. 19**, a layer **547** comprising a dielectric material is formed over piezoresistive layer **545**. Dielectric layer **547** for one embodiment may help electrically insulate piezoresistive layer **545** from one or more layers over piezoresistive layer **545**. The description pertaining to the formation and patterning of dielectric layer

540 for block **406** of **FIG. 4** similarly applies to the formation and patterning of dielectric layer **547** for block **1910** of **FIG. 19**.

[**0212**] Operations for blocks **1902**, **1904**, **1906**, **1908**, **1910**, **1912**, **1914**, **1916**, **1918**, **1920**, **1922**, **1924**, and **1926** of **FIG. 19** may be performed in any suitable order and may or may not be performed so as to overlap in time the performance of any suitable operation with any other suitable operation. As one example, piezoresistive layer **545** may be formed for block **1908** over dielectric layer **520**, dielectric layer **547** may be formed for block **1910** over piezoresistive layer **545**, heater layer **530** may be formed for block **1904** over dielectric layer **547**, and dielectric layer **540** may be formed for block **1906** over heater layer **530**. As another example, heater layer **530** and piezoresistive layer **545** may both be formed over dielectric layer **520** for blocks **1904** and **1908**. Dielectric layer **540** for one embodiment may then not be formed for block **1906**.

[**0213**] **FIG. 22** illustrates, for one embodiment, a microhotplate structure **2200** that may be formed in accordance with embodiments of flow diagram **1900** of **FIG. 19** to have piezoresistive layer **545** and heater layer **530** positioned in a side-by-side relationship. **FIG. 23** illustrates, for one embodiment, a piezoresistive chemical sensor **2300** formed in accordance with blocks **1902**, **1904**, **1906**, **1908**, **1910**, **1920**, **1922**, **1924**, and **1926** of flow diagram **1900** of **FIG. 19** to have microhotplate structure **2200**.

[**0214**] For blocks **1904** and **1908**, heater layer **530** and piezoresistive layer **545** are both formed over dielectric layer **520**. Heater layer **530** and piezoresistive layer **545** for one embodiment may each comprise the same material, such as polysilicon for example, and may each be formed and patterned as the other layer is formed and patterned to produce heater layer **530** and piezoresistive layer **545** in a suitable side-by-side relationship over platform **525**. For one embodiment, heater layer **530** and piezoresistive layer **545** may be defined to have a common lead, such as a ground lead for example, for both heater layer **530** and piezoresistive layer **545**, helping to reduce the number of leads for sensor **2300**.

[**0215**] The geometry of piezoresistive layer **545** and dielectric layer **547** and the thickness, processing, and/or chemistry of materials used, for example, may influence the elastic properties of supported platform **525** and may therefore influence the strain sensitivity of piezoresistive layer **545**. Sensors **2100** and **2300** may therefore be designed and formed as desired to help increase or decrease the strain sensitivity of piezoresistive layer **545**.

[**0216**] Although described in connection with a microhotplate structure, microcantilever structures and diaphragm structures may be similarly formed with piezoresistive layer **545** separate from heater layer **530**.

[**0217**] For other embodiments, a piezoresistive chemical sensor may be formed to have a piezoresistive layer without a heater layer. Such a piezoresistive chemical sensor may be formed in accordance with embodiments of **FIG. 19** without performing operations for blocks **1904** and **1906**.

[**0218**] Use of Sensor with Piezoresistive Layer Separate from Heater Layer

[**0219**] Sensors **2100** and **2300** may each be used with any suitable circuitry and/or equipment in any suitable manner to sense the presence of a target particle in an environment near sensor **2100** and **2300**, respectively.

[**0220**] **FIG. 24** illustrates, for one embodiment, a sensing device **2400** comprising sensor **2100**, control circuitry **2411**, a heater energization source **2412**, a piezoresistive layer energization source **2416**, and a piezoresistive layer resistance detector **2417**. Although described in connection with sensor **2100**, sensing device **2400** for another embodiment may comprise sensor **2300**. Control circuitry **2411**, heater energization source **2412**, piezoresistive layer energization source **2416**, and piezoresistive layer resistance detector **2417** collectively correspond to controller **110** of sensing device **100** of **FIG. 1**.

[**0221**] Control circuitry **2411** is coupled to heater energization source **2412**, to piezoresistive layer energization source **2416**, and to piezoresistive layer resistance detector **2417**. Control circuitry **2411** for one embodiment may also be coupled to or in wireless communication with an output device **2420**. Output device **2420** may or may not be a component of sensing device **2400**. Output device **2420** corresponds to output device **120** for sensing device **100** of **FIG. 1**.

[**0222**] Control circuitry **2411** and heater energization source **2412** generally correspond to control circuitry **811** and heater energization source **812**, respectively, of sensing device **800** of **FIG. 8**. The description of sensing device **800** of **FIG. 8** may therefore similarly apply to sensing device **2400** of **FIG. 24** where applicable.

[**0223**] Piezoresistive layer energization source **2416** and piezoresistive layer resistance detector **2417** are each coupled to piezoresistive layer **545** of sensor **2100**. Piezoresistive layer energization source **2416** may be coupled to any suitable pair of leads for piezoresistive layer **545**, and piezoresistive layer resistance detector **2417** may be coupled to any suitable pair of leads for piezoresistive layer **545**. Piezoresistive layer energization source **2416** and piezoresistive layer resistance detector **2417** for one embodiment, as illustrated in **FIG. 24**, may each be coupled to leads **542** and **544** of piezoresistive layer **545**.

[**0224**] Control circuitry **2411** may control heater energization source **2412**, piezoresistive layer energization source **2416**, and piezoresistive layer resistance detector **2417** to sense the presence of a target particle in an environment near sensor **2100** in any suitable manner. Control circuitry **2411** for one embodiment may control heater energization source **2412**, piezoresistive layer energization source **2416**, and piezoresistive layer resistance detector **2417** to sense the presence of a target particle in an environment near sensor **2100** in accordance with a flow diagram **2500** of **FIG. 25**.

[**0225**] Blocks **2502**, **2504**, **2506**, **2508**, **2510**, and **2512** of flow diagram **2500** of **FIG. 25** generally correspond to blocks **902**, **904**, **906**, **908**, **910**, and **912**, respectively, of flow diagram **900** of **FIG. 9**, only electrical resistance of piezoresistive layer **545** is sensed for block **2506** rather than that of heater layer **530** for block **906**. The description of flow diagram **900** of **FIG. 9** may therefore similarly apply to flow diagram **2500** of **FIG. 25** where applicable.

[**0226**] For block **2506**, control circuitry **2411** controls piezoresistive layer energization source **2416** to energize piezoresistive layer **545** of sensor **2100** and controls piezoresistive layer resistance detector **2417** to sense electrical resistance of piezoresistive layer **545**. Piezoresistive layer energization source **2416** may comprise any suitable circuitry to energize piezoresistive layer **545** in any suitable manner, and piezoresistive layer resistance detector **2417** may comprise any suitable circuitry to sense resistance of piezoresistive layer **545** in any suitable manner.

[**0227**] Although illustrated as physically separate components, heater energization source **2412** and piezoresistive layer energization source **2416** for one embodiment may comprise common circuitry to energize heater layer **530** and piezoresistive layer **545**, respectively, under control of control circuitry **2411**.

[**0228**] Array of Chemical Sensors

[**0229**] **FIG. 26** illustrates, for one embodiment, a sensing device **2600** comprising a controller **2610** and a plurality of chemical sensors **150** of **FIG. 1**. Controller **2610** is coupled to each sensor **150** to sense the presence of a target particle in an environment near that sensor **150**. Each sensor **150** is responsive to change in volume of a sensing material when exposed to one or more target particles. Each sensor **150** may be local to or remote from any other sensor **150** and/or controller **2610**. Controller **2610** for one embodiment may also be coupled to or in wireless communication with an output device **2620**. Output device **2620** may or may not be a component of sensing device **2600**. Output device **2620** corresponds to output device **120** for sensing device **100** of **FIG. 1**.

[**0230**] Each sensor **150** may or may not be similarly formed as any other sensor **150**. As one example, one sensor **150** may have a microhotplate structure while another sensor may have a microcantilever structure. As another example, one sensor **150** may have one sensing material to identify one target particle while another sensor may have another sensing material to sense another target particle.

[**0231**] Sensing device **2600** for one embodiment may comprise two or more similarly formed sensors **150** for purposes of redundancy. Sensing device **2600** for one embodiment may comprise two or more similarly formed sensors **150** to sense the same target particle with the same sensing material at different temperatures. Sensing device **2600** for one embodiment may comprise two or more differently formed sensors **150** to sense different target particles or to sense the same target particle with different sensing materials.

[**0232**] Although described as comprising a plurality of sensors **150** responsive to change in volume of a sensing material when exposed to one or more target particles, sensing device **2600** for another embodiment may comprise at least one sensor **150** responsive to change in volume of a sensing material when exposed to one or more target particles and at least one other type of sensor that senses one or more target particles in another suitable manner.

[**0233**] In the foregoing description, one or more embodiments of the present invention have been described. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit or scope of the present invention as defined in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

What is claimed is:

1. A sensor comprising:

sensing material that changes volume when exposed to one or more target particles; and

a transducing platform comprising a piezoresistive component to sense change in volume of the sensing material, wherein the sensing material is positioned over the piezoresistive component.

2. The sensor of claim 1, wherein the transducing platform comprises one of a microhotplate structure, a microcantilever structure, and a diaphragm structure.

3. The sensor of claim 1, wherein the transducing platform comprises a heater component to heat the sensing material.

4. The sensor of claim 1, in combination with a controller coupled to the transducing platform to sense a relative volume of the sensing material to identify whether a target particle is near the sensing material.

5. The sensor of claim 1, wherein a target particle is hydrogen.

6. A sensor comprising:

a first layer comprising a piezoresistive material to sense change in volume of one or more layers over the first layer; and

a second layer over the first layer, the second layer comprising material that changes volume when exposed to one or more target particles.

7. The sensor of claim 6, wherein the piezoresistive material of the first layer is to heat the second layer when current is induced to flow through the piezoresistive material.

8. The sensor of claim 7, comprising a heat distribution layer.

9. The sensor of claim 6, comprising a third layer to heat the second layer when current is induced to flow through the third layer.

10. The sensor of claim 9, comprising a heat distribution layer.

11. The sensor of claim 6, comprising a contact layer conductively coupled to the second layer.

12. The sensor of claim 6, comprising a platform to support the first and second layers over a hollowed portion of a substrate.

13. The sensor of claim 12, wherein the platform is deflectable.

14. The sensor of claim 6, comprising a membrane layer to support the first and second layers over a hollowed portion of a substrate.

15. The sensor of claim 6, wherein the first layer has two electrical leads and wherein the sensor has only the two electrical leads defined by the first layer.

16. The sensor of claim 6, wherein the first layer comprises one of polycrystalline silicon, barium titanate ($BaTiO_3$), silicon (Si), lead zirconium titanate ($(Pb,Zr)TiO_3$), and chromium nitride (CrN).

17. The sensor of claim 6, wherein the second layer comprises at least one of a rare earth element, a Group II element, lithium (Li), a Group VB element, palladium (Pd), titanium (Ti), zirconium (Zr), and a polymer.

18. The sensor of claim 6, wherein the first layer comprises polycrystalline silicon and the second layer comprises yttrium (Y).

19. The sensor of claim 6, wherein a target particle is hydrogen.

20. An apparatus comprising:

sensing material that changes volume when exposed to one or more target particles;

means for sensing change in volume of the sensing material; and

means for controlling temperature of the sensing material.

21. A sensing device comprising:

a sensor comprising a piezoresistive layer and sensing material over the piezoresistive layer, wherein the sensing material changes volume when exposed to one or more target particles; and

a controller to sense a resistance of the piezoresistive layer.

22. The sensing device of claim 21, wherein the controller comprises:

a source to energize the piezoresistive layer to heat the sensing material;

a detector to sense a resistance of the piezoresistive layer; and

control circuitry to control the source and to identify a presence of a target particle near the sensing material based on the sensed resistance of the piezoresistive layer.

23. The sensing device of claim 22, wherein the controller comprises another source to energize the sensing material.

24. The sensing device of claim 23, wherein the controller comprises another detector to sense a resistance of the sensing material; and

wherein the control circuitry is to identify a presence of a target particle near the sensing material based on the sensed resistance of the piezoresistive layer and/or based on the sensed resistance of the sensing material.

25. The sensing device of claim 21, wherein the sensor comprises a heater layer and wherein the controller comprises:

a first source to energize the heater layer to heat the sensing material;

a second source to energize the piezoresistive layer;

a detector to sense a resistance of the piezoresistive layer; and

control circuitry to control the first source and to identify a presence of a target particle near the sensing material based on the sensed resistance of the piezoresistive layer.

26. The sensing device of claim 25, wherein the controller comprises a third source to energize the sensing material.

27. The sensing device of claim 26, wherein the controller comprises another detector to sense a resistance of the sensing material; and

wherein the control circuitry is to identify a presence of a target particle near the sensing material based on the sensed resistance of the piezoresistive layer and/or based on the sensed resistance of the sensing material.

28. The sensing device of claim 21, wherein the piezoresistive layer comprises one of polycrystalline silicon, barium titanate ($BaTiO_3$), silicon (Si), lead zirconium titanate ($(Pb,Zr)TiO_3$), and chromium nitride (CrN).

29. The sensing device of claim 21, wherein the sensing material comprises at least one of a rare earth element, a Group II element, lithium (Li), a Group VB element, palladium (Pd), titanium (Ti), zirconium (Zr), and a polymer.

30. The sensing device of claim 21, wherein the piezoresistive layer comprises polycrystalline silicon and the sensing material comprises yttrium (Y).

31. The sensing device of claim 21, wherein a target particle is hydrogen.

32. A method comprising:

forming over a substrate a first layer comprising a piezoresistive material to sense change in volume of one or more layers over the first layer; and

forming over the first layer a second layer comprising a material that changes volume when exposed to a target particle.

33. The method of claim 32, wherein the forming the first layer comprises forming the first layer to comprise one of polycrystalline silicon, barium titanate ($BaTiO_3$), silicon (Si), lead zirconium titanate ($(Pb,Zr)TiO_3$), and chromium nitride (CrN).

34. The method of claim 32, wherein the forming the second layer comprises forming the second layer to comprise at least one of a rare earth element, a Group II element, lithium (Li), a Group VB element, palladium (Pd), titanium (Ti), zirconium (Zr), and a polymer.

35. The method of claim 32, wherein the forming the first layer comprises forming the first layer to comprise polycrystalline silicon; and

wherein the forming the second layer comprises forming the second layer to comprise yttrium (Y).

36. The method of claim 32, wherein the forming the first layer comprises forming the piezoresistive material to heat the second layer when current is induced to flow through the piezoresistive material.

37. The method of claim 36, comprising forming a heat distribution layer.

38. The method of claim 32, comprising forming a third layer to heat the second layer when current is induced to flow through the third layer.

39. The method of claim 38, comprising forming a heat distribution layer.

40. The method of claim 32, comprising forming a contact layer for conductive coupling to the second layer.

41. The method of claim 32, comprising defining a platform to support the first and second layers over a hollowed portion of a substrate.

42. The method of claim 41, wherein the defining the platform comprises defining the platform to be deflectable.

43. The method of claim 32, comprising forming a membrane layer spanning a hollowed portion of a substrate to support the first and second layers over the hollowed portion.

44. The method of claim 32, wherein a target particle is hydrogen.

45. A method comprising:

sensing a resistance of a piezoresistive layer with sensing material over the piezoresistive layer, wherein the sensing material changes volume when exposed to one or more target particles; and identifying whether a target particle is near the sensing material based on the sensed resistance of the piezoresistive layer.

46. The method of claim 45, comprising:

energizing the piezoresistive layer to heat the sensing material.

47. The method of claim 45, comprising:

energizing the sensing material.

48. The method of claim 45, comprising sensing a resistance of the sensing material;

wherein the identifying comprises identifying whether a target particle is near the sensing material based on the sensed resistance of the piezoresistive layer and/or based on the sensed resistance of the sensing material.

49. The method of claim 45, comprising:

energizing a heater layer to heat the sensing material.

50. A sensing device comprising:

an array of sensors, wherein at least one sensor comprises a piezoresistive layer and sensing material over the piezoresistive layer and wherein the sensing material changes volume when exposed to one or more target particles; and

a controller coupled to the array of sensors to sense a resistance of the piezoresistive layer of at least one sensor.

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